ASEN 4028 Senior Projects - Spring 2019

Manufacturing Status Review

ARGUS

Auto-Tracking RF Ground Unit for S-Band

Team: Trevor Barth, Anahid Blaisdell, Adam Dodge, Geraldine Fuentes, Thomas Fulton, Adam Hess, Janell Lopez, Diana Mata, Tyler Murphy, Stuart Penkowsky, Michael Tzimourakas

ENGINEERING EXCELLENCE FUND

Advisor: Professor Dennis Akos

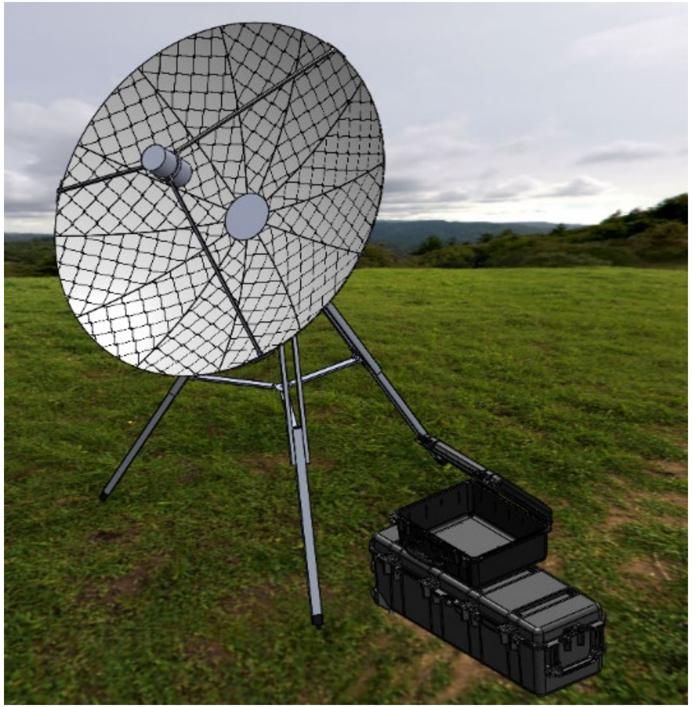
Customer: Raytheon

Project Overview

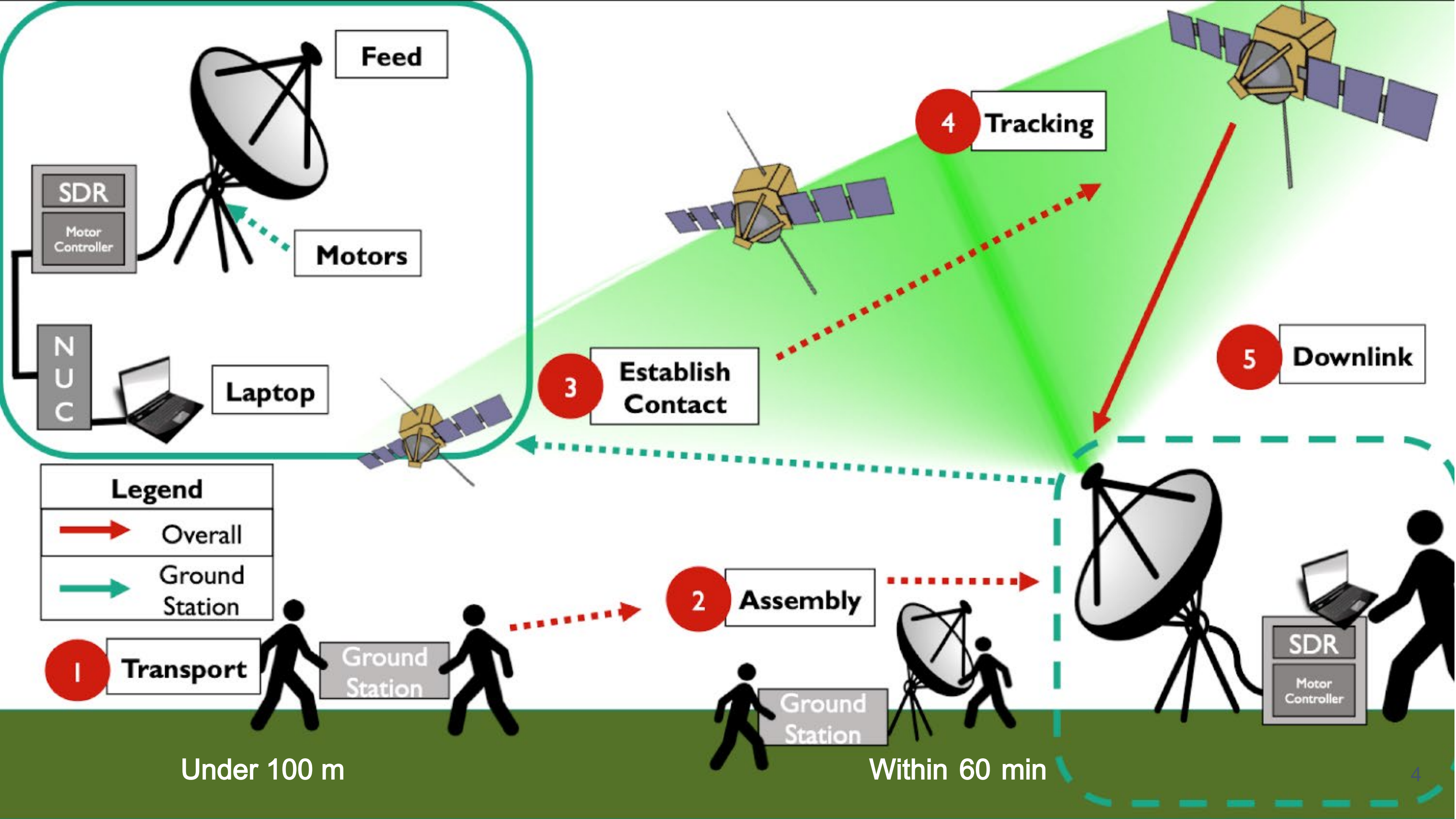
Project Overview | Project Schedule | Mechanical | Software | Electrical | System Integration | Budget

Project Purpose & Objectives

Mission Statement: The ARGUS ground station is designed to be able to track a LEO satellite and receive a telemetry downlink using a platform that is both portable and more affordable than current S-Band ground stations.



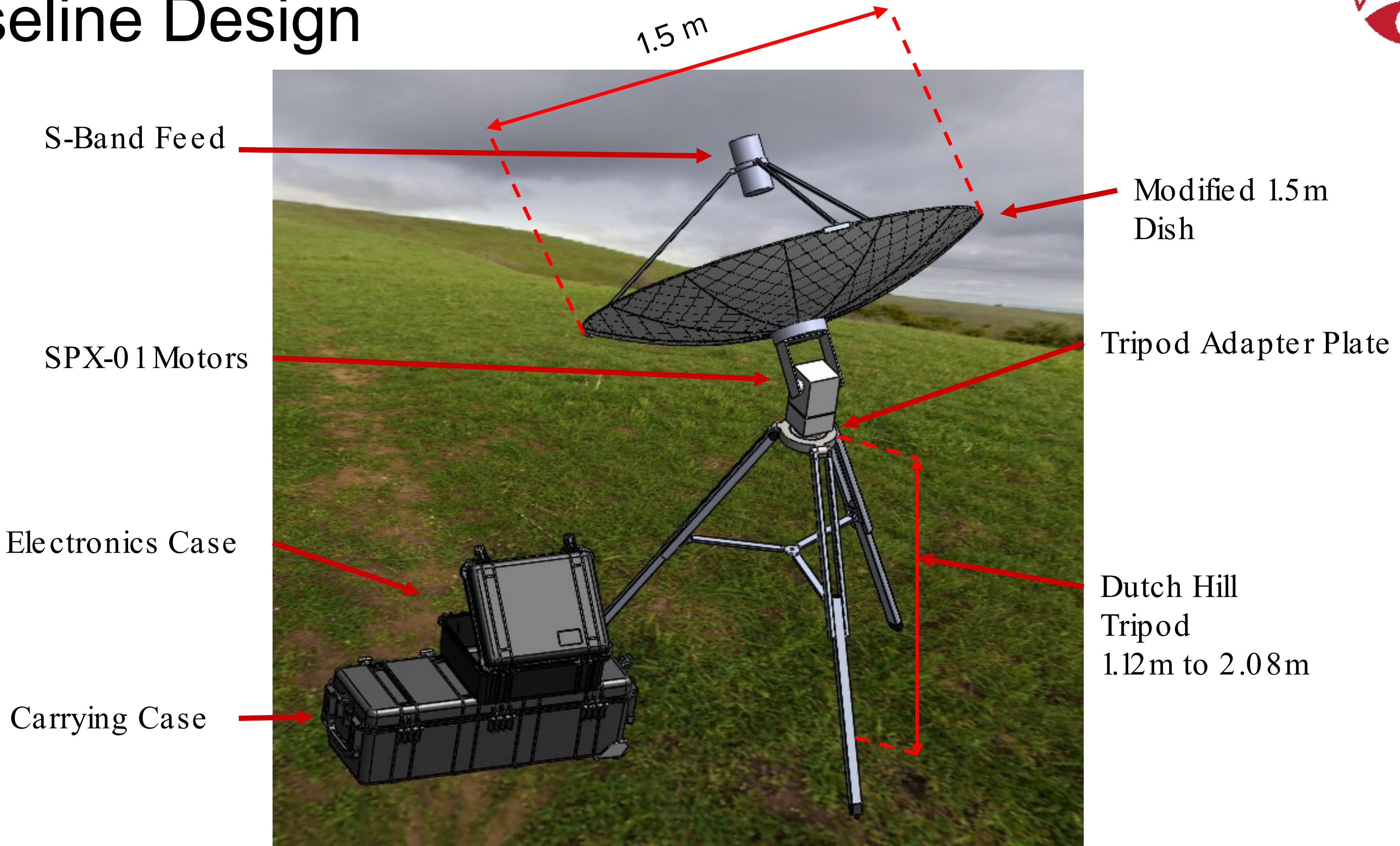
- Commercial-off-the-shelf (COTS) where possible
- Interface with user laptop
- Portable: 46.3 kg (102 lbs), able to be carried a distance of 100 meters by two people


Feed
SDR
Motor Controller
Motors
NUC
Laptop
Legend
Overall
Ground Station
1 Transport
Ground Station
2 Assembly
Ground Station
3 Establish Contact
4 Tracking
5 Downlink
SDR
Motor Controller
Under 100 m
Within 60 min

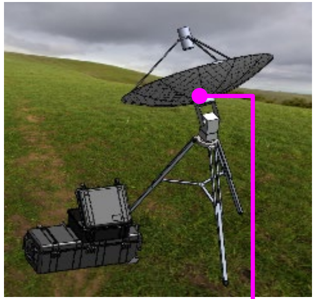
Levels of Success

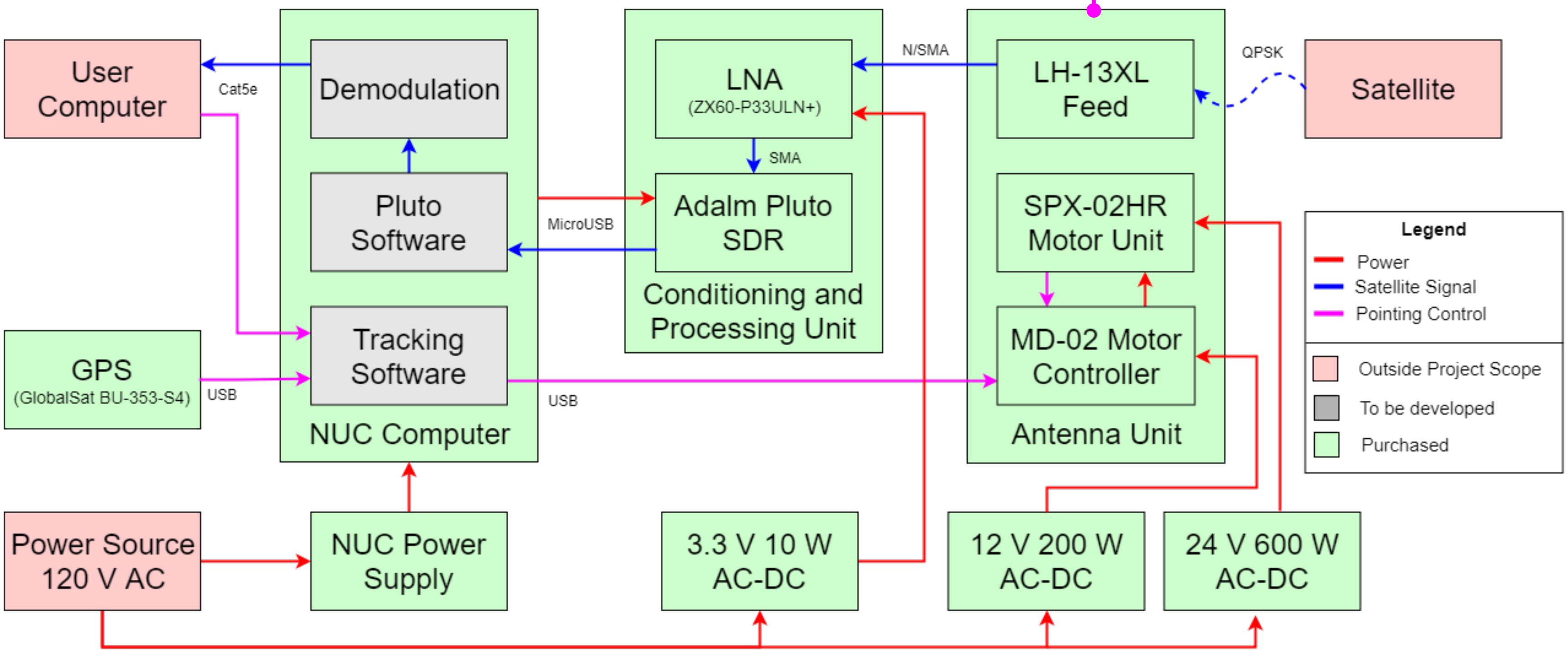
	Mechanical	Software	Electronics
Level 1	- Transportable in back of truck - Assembled < 6 hours - Track LEO satellites at 5°/sec - Communicate with LEO satellite at 10+° elevation above horizon	- Take TLE data and for az/el pointing commands - Data packets demodulated using QPSK - BER $\leq 10^{-5}$	- Provide power to all sub-systems - System used with monitor, keyboard, and mouse
Level 2	- Transportable by unpowered rolling vehicle - Assembled < 2 hours - Reconfigurable for other frequency bands	- Able to predict LEO satellite locations to less than 2.75° deg accuracy - Reconfigurable for other frequency bands	- System used with personal laptop interfaced using secure shell over a Cat-5 ethernet cable - Reconfigurable for other frequency bands
Level 3	- Two people carry 100 meters - Assembled < 1 hour	- BER $\leq 10^{-9}$	

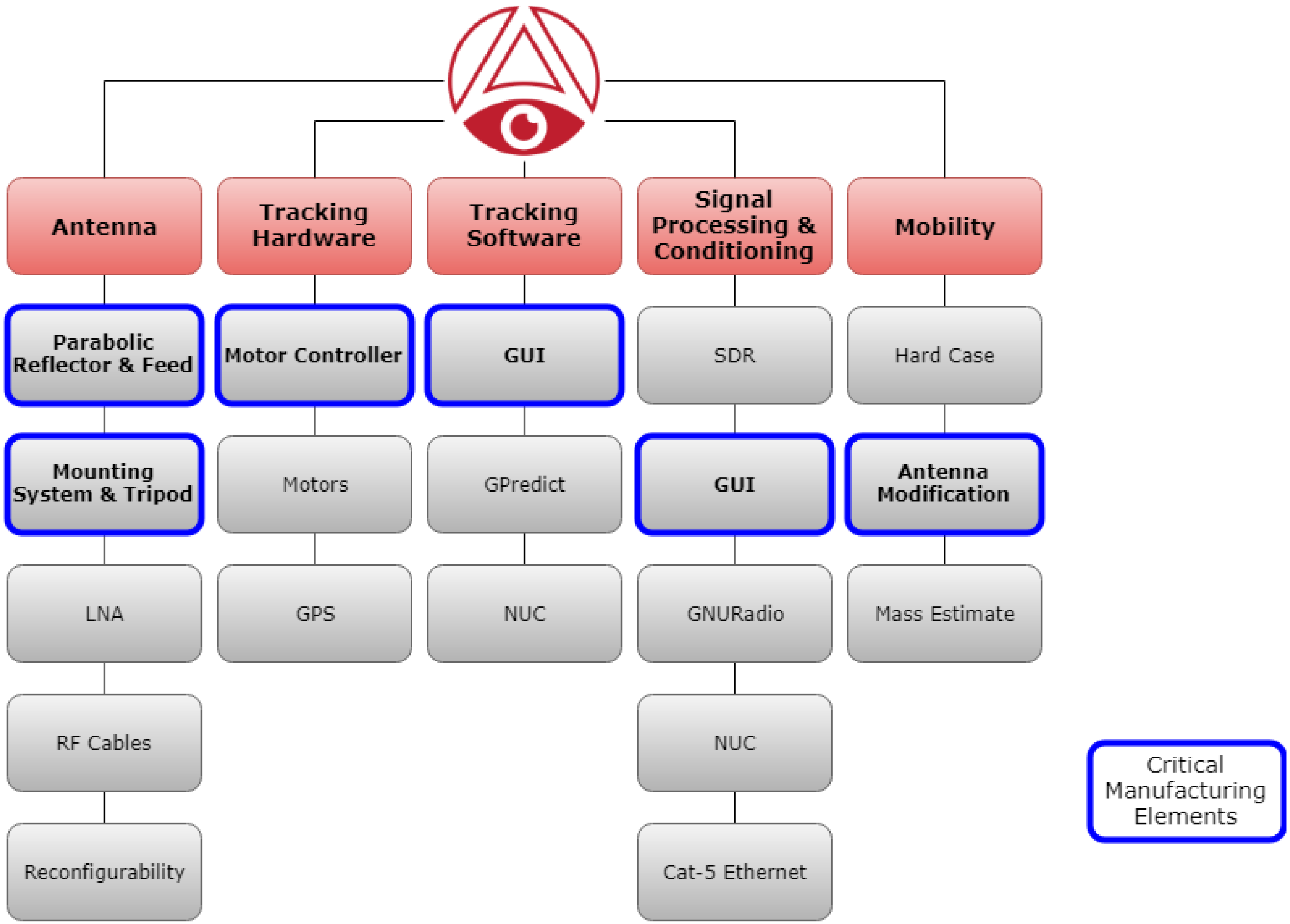
Baseline Design



Functional Block Diagram





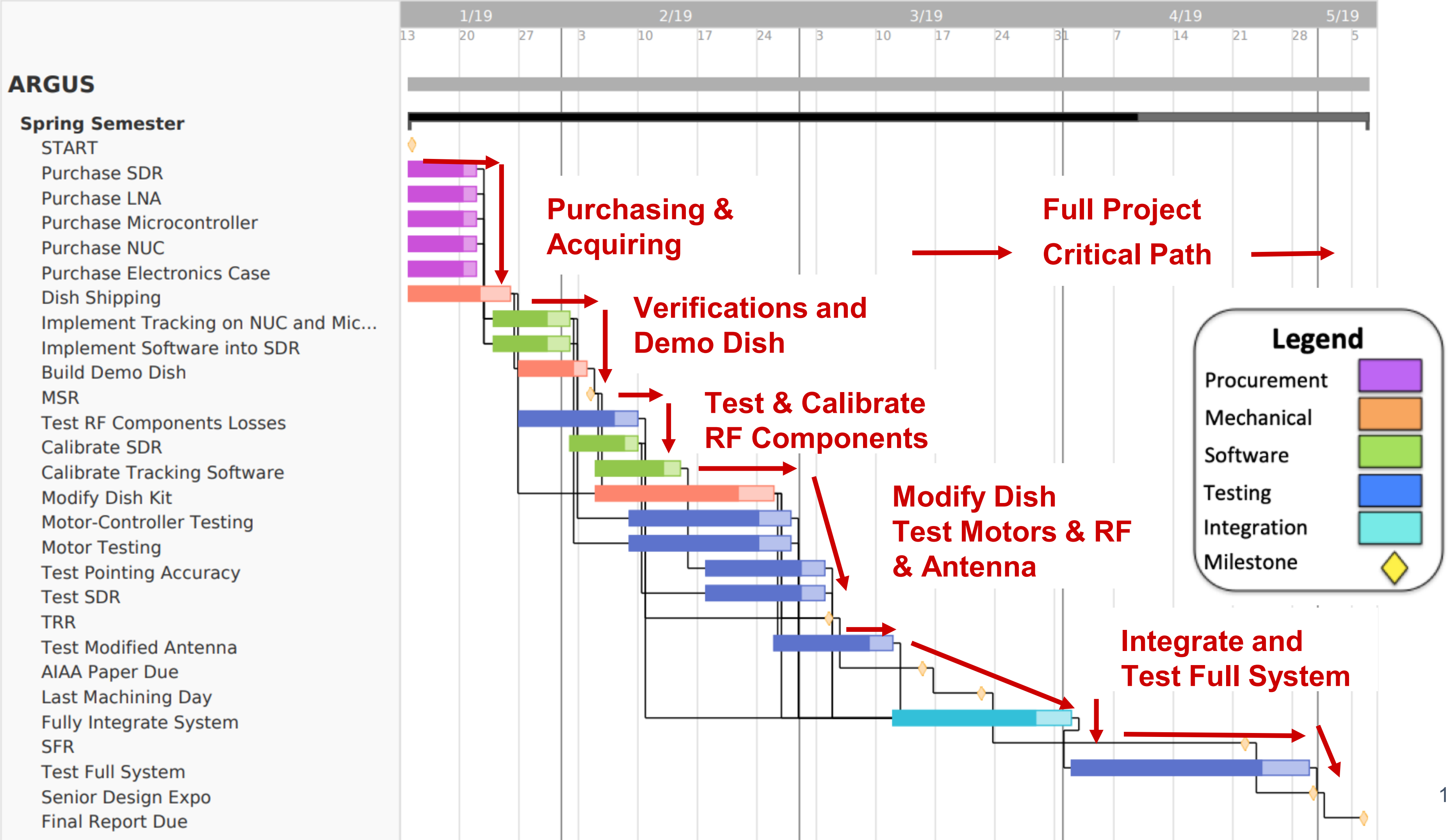

Antenna
Tracking Hardware
Tracking Software
Signal Processing & Conditioning
Mobility
Parabolic Reflector & Feed
Mounting System & Tripod
LNA
RF Cables
Reconfigurability
Motor Controller
Motors
GPS
GUI
GPredict
NUC
SDR
GUI
GNURadio
NUC
Cat-5 Ethernet
Hard Case
Antenna Modification
Mass Estimate
Critical Manufacturing Elements

Critical Manufacturing Elements

CME	Reason	Predicted Required Hours
Dish Modifications	Precise modification required for reliable communication	80
Mounting System & Tripod	Stable antenna base critical to closing link with satellite	15
Command Motor Controller & Drive Motors	Several steps of software must work together to achieve accurate control	40
Tracking GUI & Signal GUI Interfacing	Software must work in conjunction with all electronics and user simultaneously	40

Project Schedule

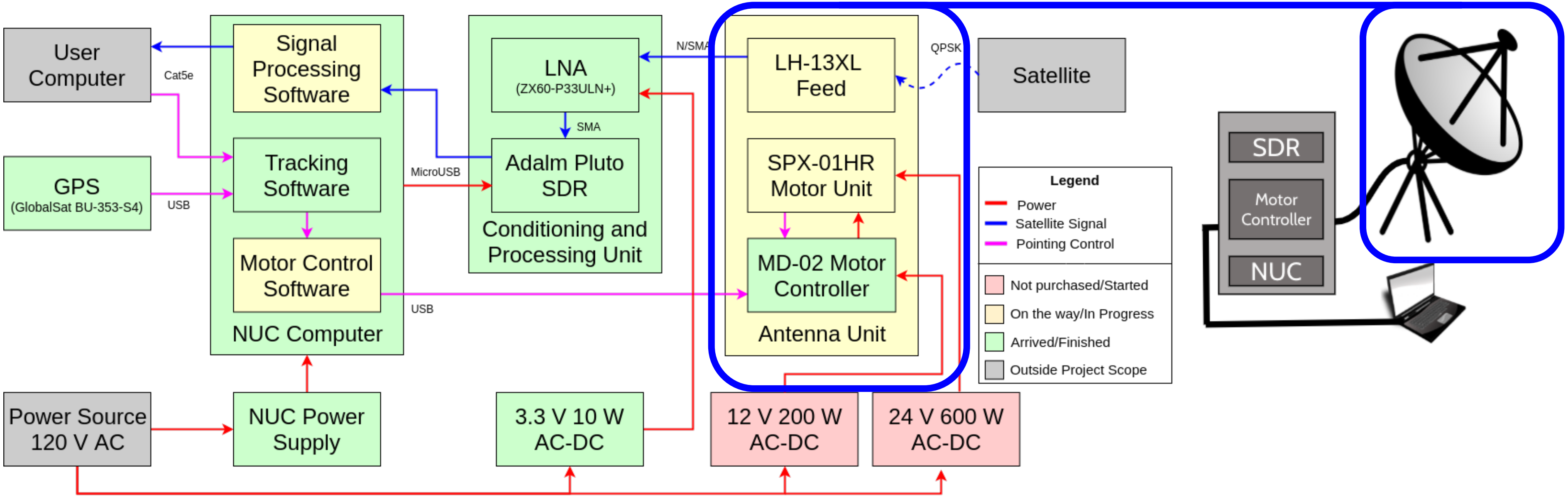
Project Overview | **Project Schedule** | Mechanical | Software | Electrical | System Integration | Budget



ARGUS
Spring Semester
START
Purchase SDR
Purchase LNA
Purchase Microcontroller
Purchase NUC
Purchase Electronics Case
Dish Shipping
Implement Tracking on NUC and Mic...
Implement Software into SDR
Build Demo Dish
MSR
Test RF Components Losses
Calibrate SDR
Calibrate Tracking Software
Modify Dish Kit
Motor-Controller Testing
Motor Testing
Test Pointing Accuracy
Test SDR
TRR
Test Modified Antenna
AIAA Paper Due
Last Machining Day
Fully Integrate System
SFR
Test Full System
Senior Design Expo
Final Report Due
1/19
2/19
3/19
4/19
5/19
13 20 27 3 10 17 24 3 10 17 24 31 7 14 21 28 5
Purchasing & Acquiring
Full Project Critical Path
Verifications and Demo Dish
Test & Calibrate RF Components
Modify Dish Test Motors & RF & Antenna
Integrate and Test Full System
Legend
Procurement
Mechanical
Software
Testing
Integration
Milestone

Manufacturing:
Mechanical

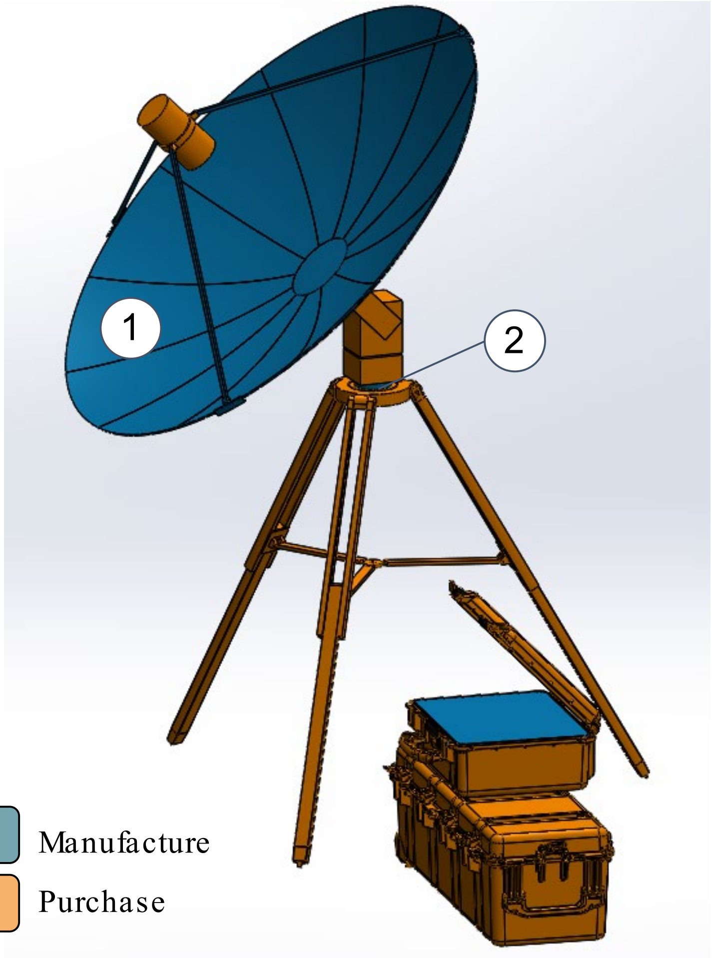
Critical Manufacturing Area: Mechanical



Mechanical - Components

	Manufacture	Purchase
1	Demo Dish	Dish Kits ✓
1	Dish Modification	Modification Materials ✓
	LNA Shield	Motor System ✓
	Tripod Feet	Tripod ✓
	Case Modification	Hardware Case
2	Motor System Mount	Electronics Case

Critical Element



Manufacture
Purchase

Mechanical - Demonstration Dish

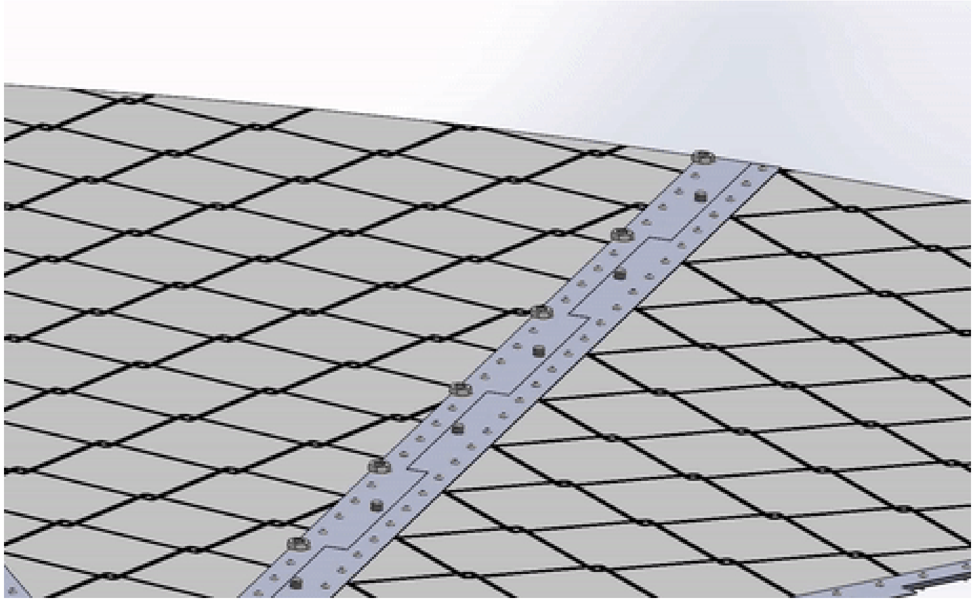
- Demonstration Dish Purpose
  - To learn basic assembly process for modified version
  - To learn how to make modifications

- Lessons Learned:
  - Large flat surfaces forced into curves are not ideal
    - Smaller sections will be easier: less binding/folding
  - Lots of slop in center hub -- may modify
  - Assembly required 3 people
  - Rivets and mesh are very strong
  - Modified dish will be much easier to assemble

Status: Completed ✓ || Hours: 18 of 18 || Deadline: 2/4/2019

Mechanical - Modified Dish

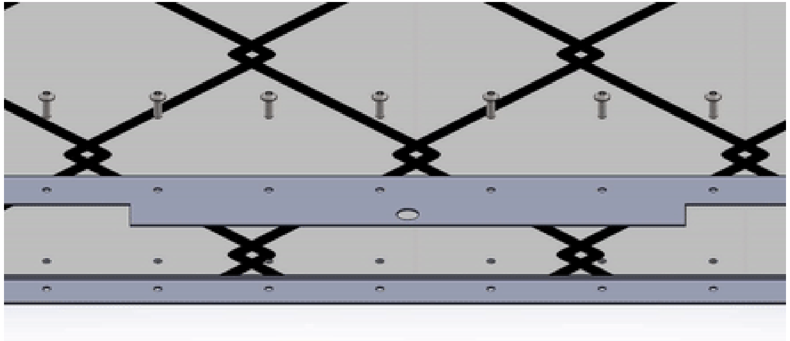
- Slow shipping of dish kit caused later start time
  - Work on off-days and weekends to offset slow start
- All additional components and tools purchased and prepared
- Challenges:
  - Splitting up outer ring for panels
  - Buckling of the mesh

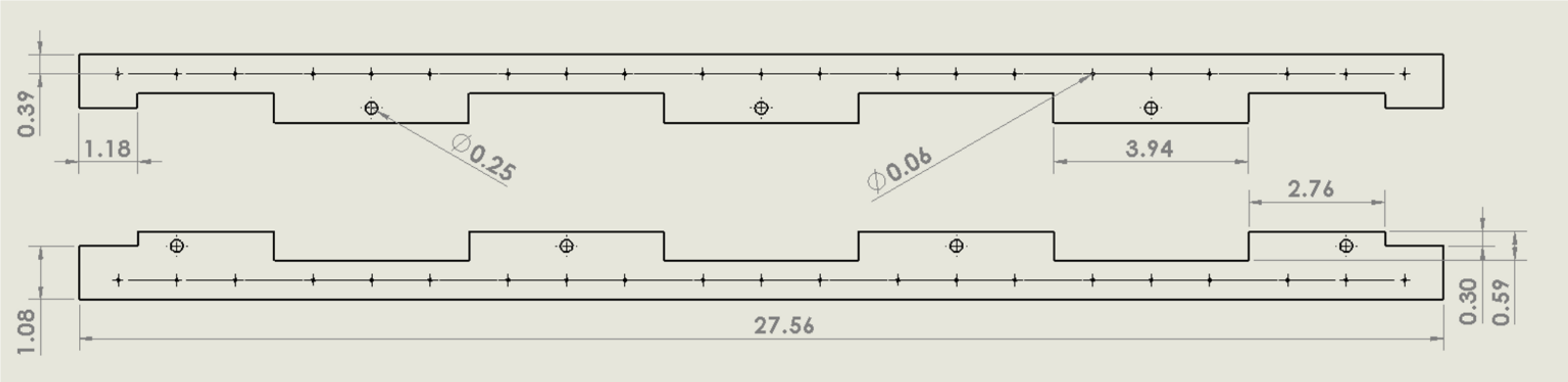


Status: On Track || Hours: 3 of 83 || Deadline: 2/28/2019

Mechanical - Modified Dish

- Still need to machine aluminum tabs
  - Can be done in stacks in CNC machine
  - Files are prepared
  - Doing test print
- Modification to center hub

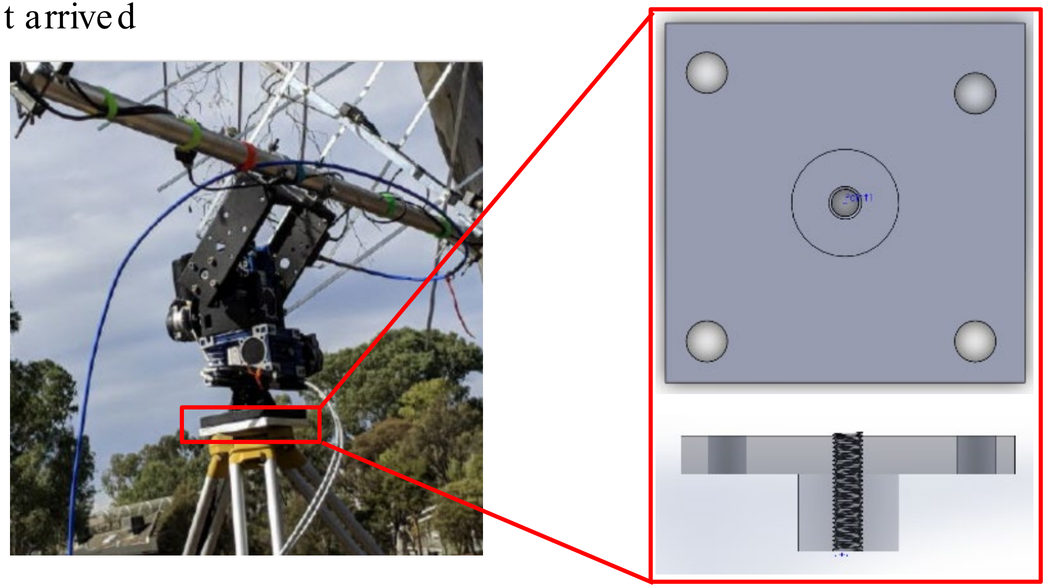




Status: On Track || Hours: 3 of 83 || Deadline: 2/28/2019

Mechanical - Tripod and Motor System Mount

- Changed selected tripod from CDR to accommodate uneven ground
- Need to create adapter plate to connect tripod to motors
    - Tripod and motor have not arrived
- Current plan:
    - Surveying tripod
    - Create adapter plate



Status: **Delayed** || Hours: 0 of 15 || Deadline: 2/25/2019

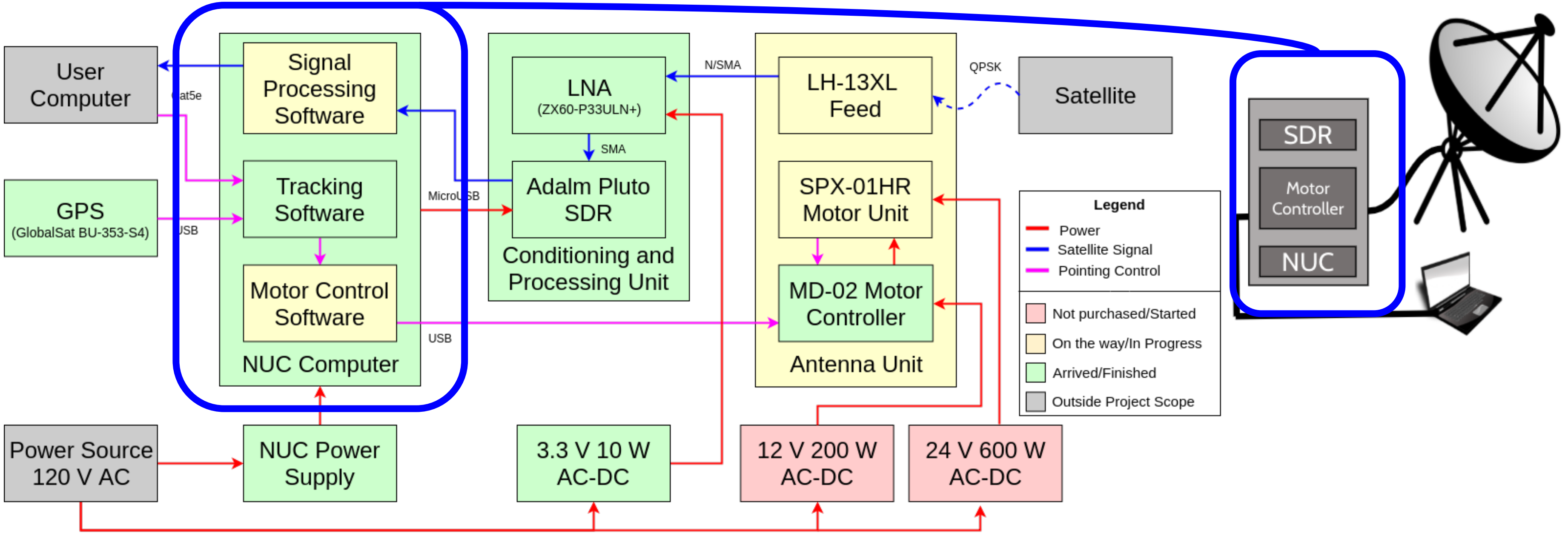
Mechanical - Progress Report

	Task	Hours Completed/Total Working Hours	Expected Deadline Date
Demo Dish	Assemble dish	18/18	Completed
Dish Modification	Cut tabbed aluminum sheets	2/12	2/8/19
	Cut mesh panels	1/4	2/6/19
	Assemble panels	0/20	2/11/19
	Drill connecting holes in ribs	0/12	2/11/19
	Assemble full dish	0/20	2/28/19
	Motor/Tripod interface plate	0/15	2/25/19

Manufacturing: **Software**

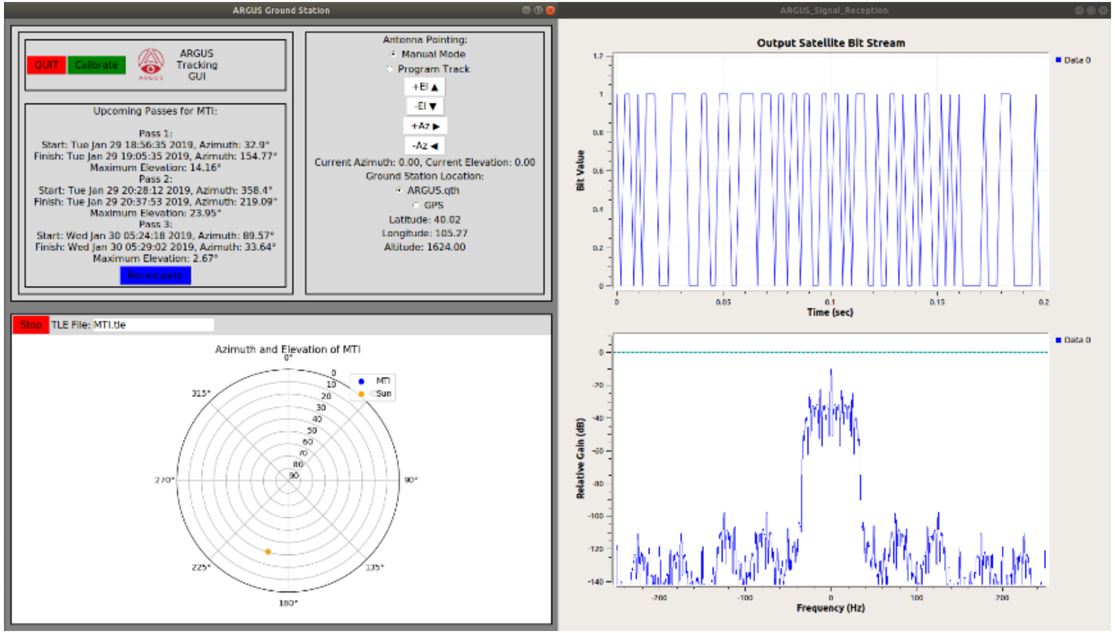
Project Overview | Project Schedule | Mechanical | Software | Electrical | System Integration | Budget

Critical Manufacturing Area: Software

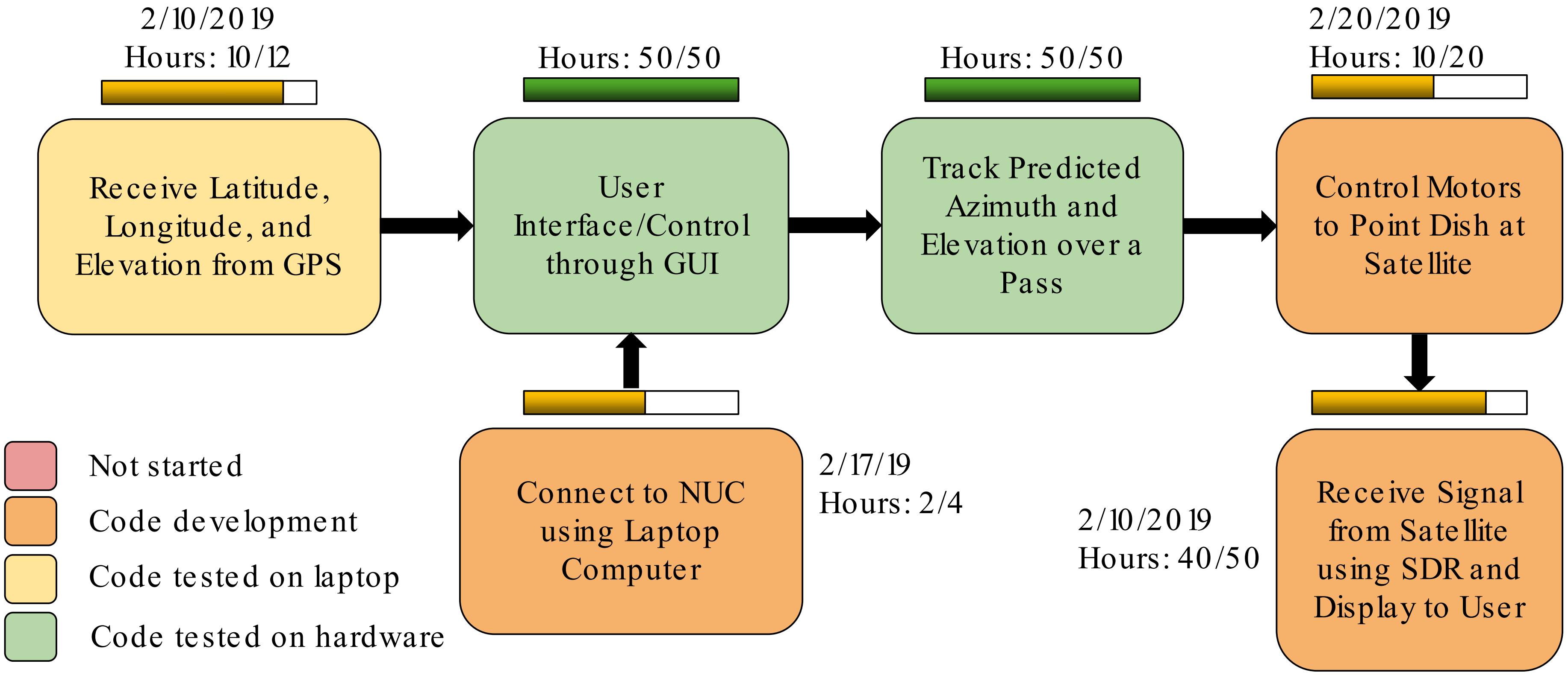


Software - Overview

- Overview:
  - Tracks and displays future passes and current location of specified satellite
  - Control antenna pointing position
  - Receive signal, display, and save bit stream to file
- Inputs:
  - Lat/Lon/Alt from GPS or QTH file
  - TLE text file
  - Signal Frequency & Bandwidth
  - Adalm Pluto Signal
- Outputs:
  - Binary text file of demodulated signal
  - Tracking GUI & Signal Processing GUI

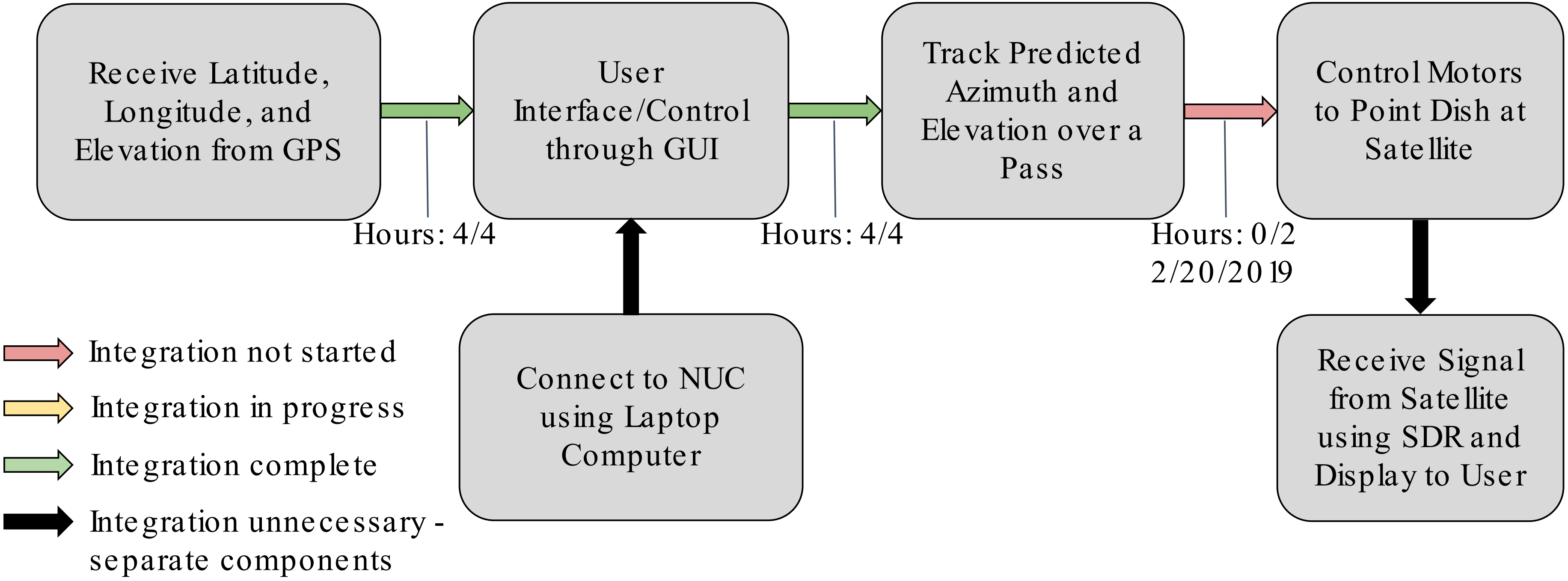


Software - Status



Status: On Track

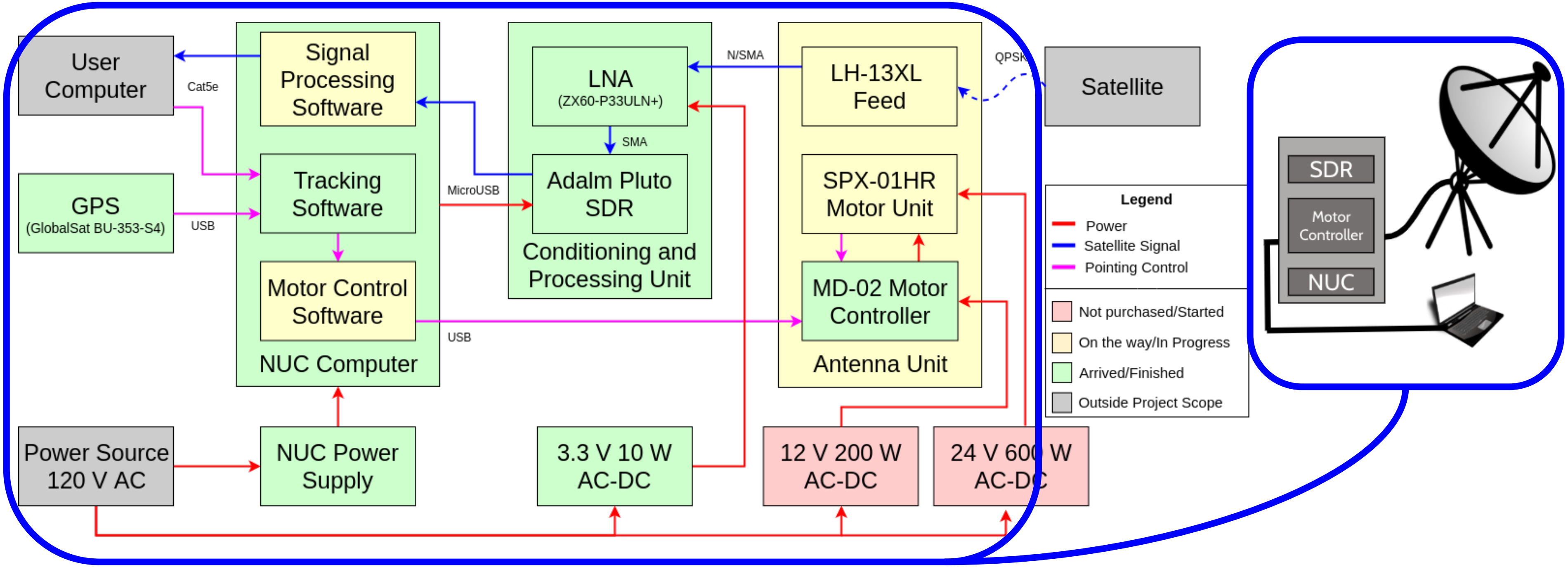
Software - Integration



Status: On Track

Manufacturing: **Electrical**

Critical Manufacturing Area: Electrical



Electrical - Components

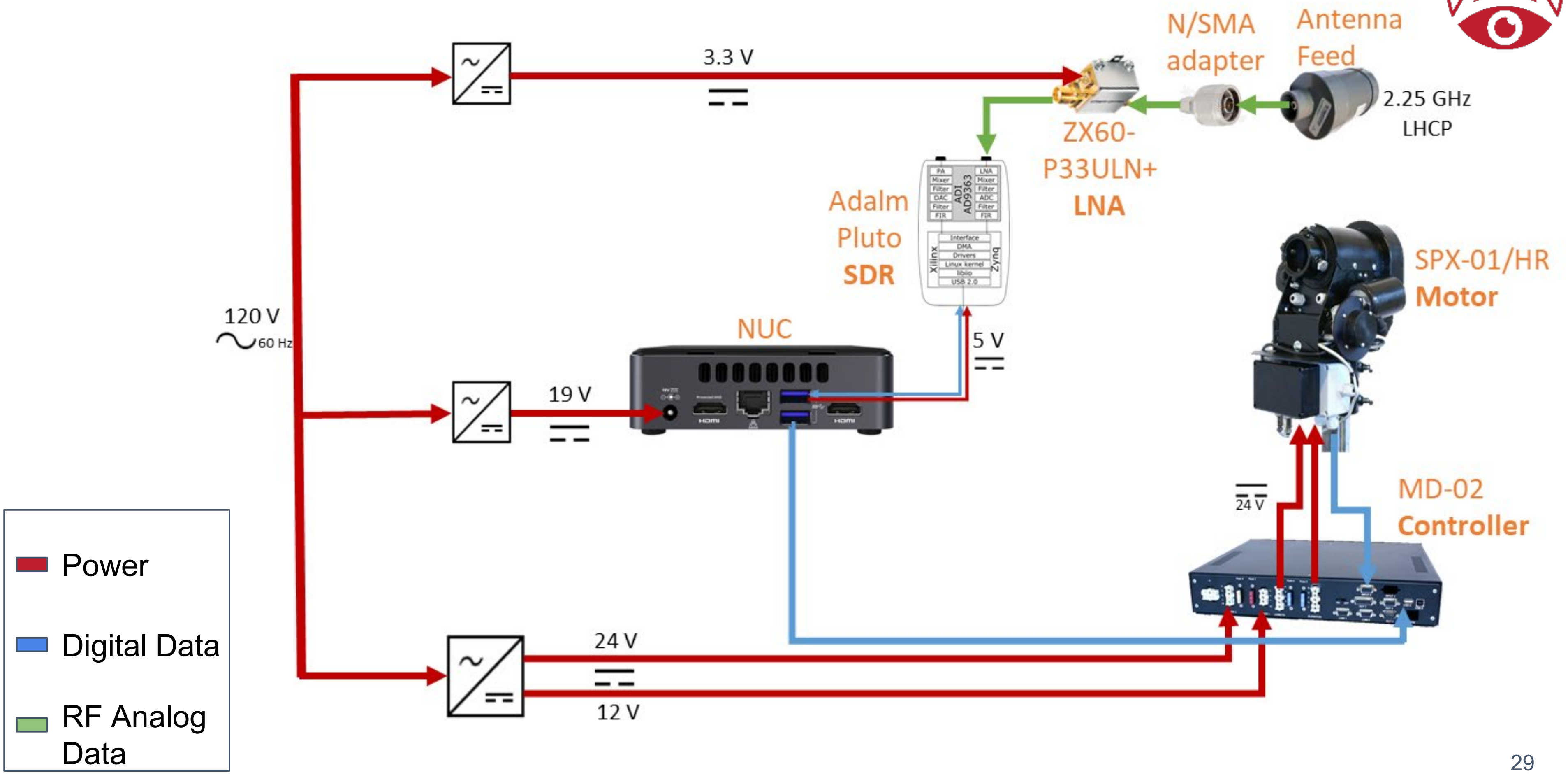
Manufacturing
Wiring Assembly
Radio Frequency Path Design
Power Supply

Critical Element

Purchased
Cables ✓
LNA ✓
Motor Controller ✓
NUC ✓
GPS ✓
SDR ✓
Power Converters
Feeds

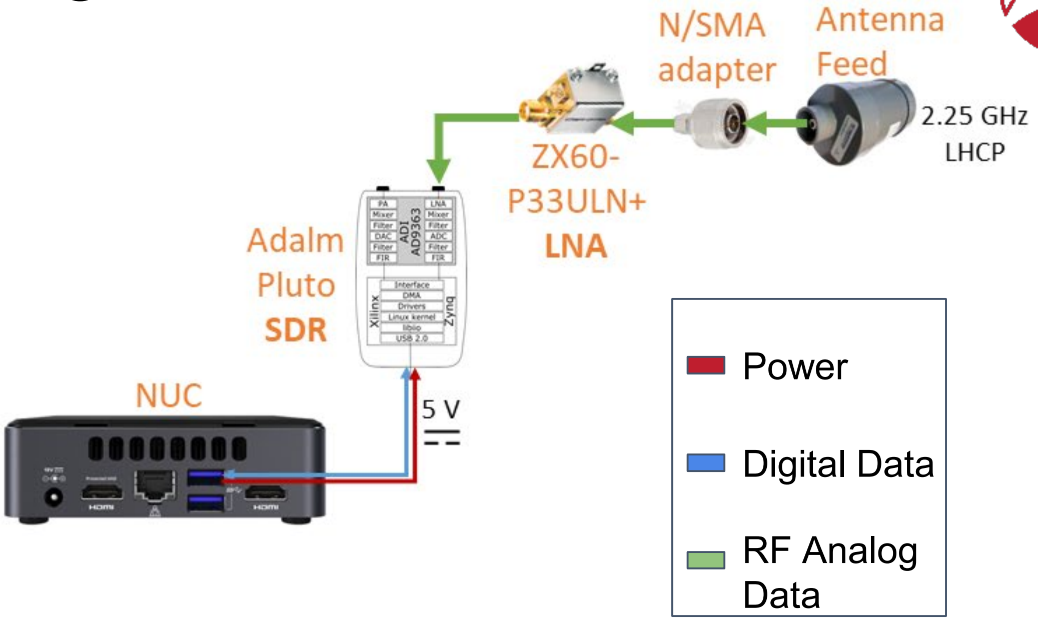
Electrical Status Report	Task	Hours Completed/Total Man Hours	Expected Deadline Date
Wiring Assembly	Feed to SDR	0/0.5	2/15/19
	NUC Connections	0/0.5	2/15/19
	Motor Connections	0/1	2/30/19
Radio Frequency Path Design	Component Assembly	0/0.5	2/08/19
	Loss Testing	2/3	2/08/19
	Demo Dish Gain Testing	0/10	2/16/19
	Modified Dish Gain Testing	0/10	3/08/19
Power Supply	LNA Power Interface	0/2	2/08/19
	Motor Interface	0/3	2/20/19
	NUC interface	1/1	Completed

Electrical - Overview



Electrical - RF Path Design

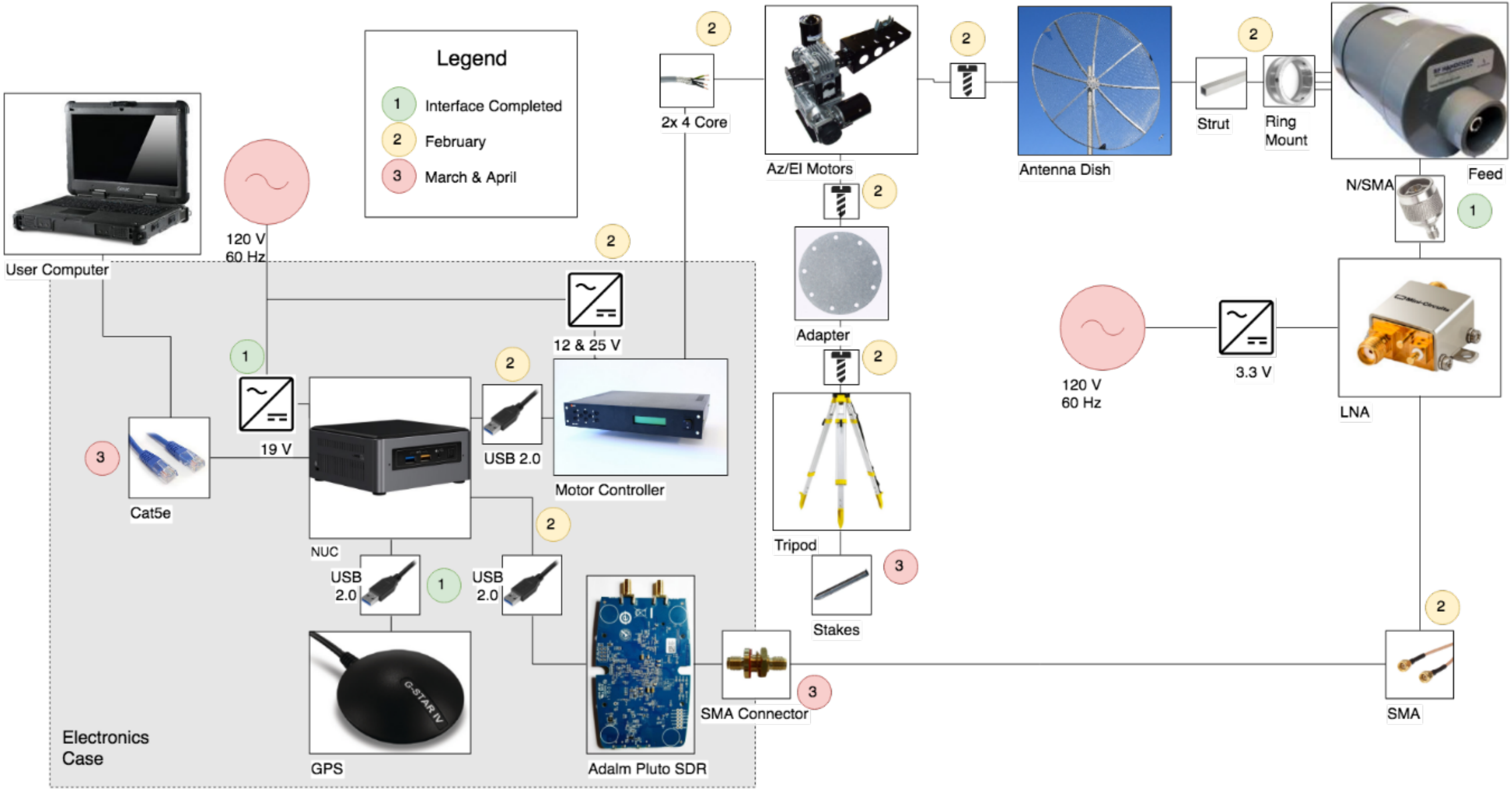
Component Loss Testing	2/3 hours	2/08/19
Assembly	0/0.5 hours	2/08/19
Demo Dish Gain Testing	0/10 hours	2/16/19
Modified Dish Gain Testing	0/10 hours	3/08/19



- Gain test depends on dish construction
  (Estimated modified dish completion 2/28/19)

System Integration

System Integration Plan



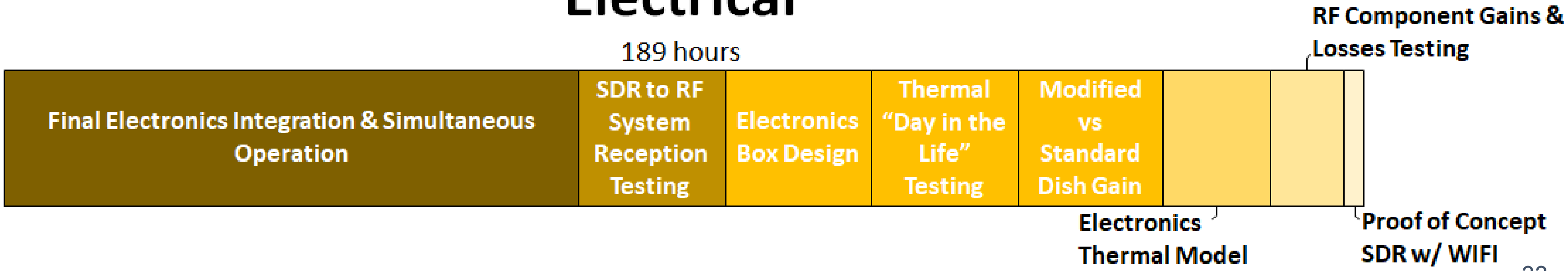
ARGUS

Mechanical

284 hours

Electrical

189 hours



ARGUS

Mechanical 284 hours	Electronics 189 hours	Software 140 hours	Management 130 hours

Software

140 hours

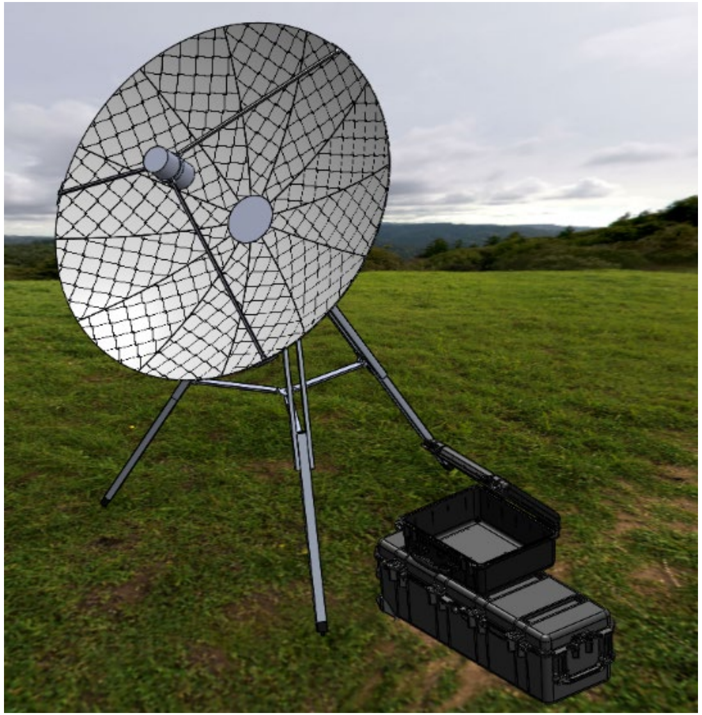
Compile Software User Guide	Verify Calibration Method and Program	User/GUI Interfacing and Data Transfer over Cat5e	RF Circuit Processing and Final Integration	Satellite Pass Power Verification	Send Serial Comms to Motor Controller

Management

130 hours

Full System Integration Coordination	Compile Full System User Guide	Formatting (MSR, TSR, AIAA, SFR)	Test Protocols Compilation	Component and Interface Documentation

Overall Project Status:On Track



Under budget with 38% left
Currently 33% total labor accomplished

Critical Elements:

- Modification of Dish
- System Integration
- Program Demonstration

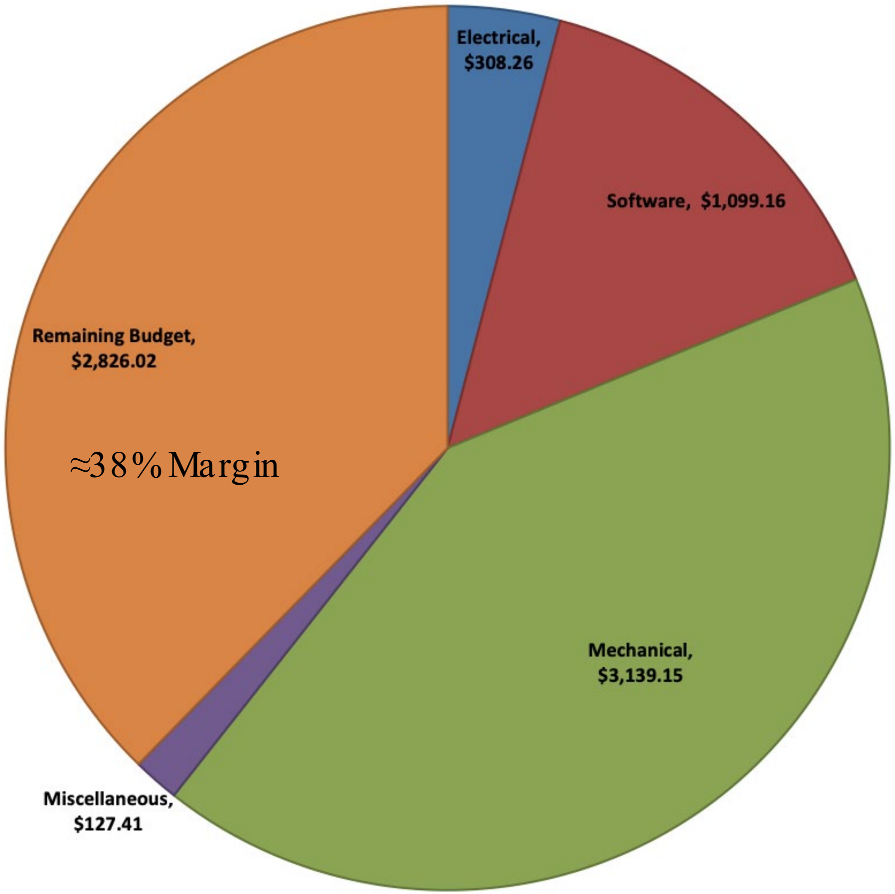
Subsystem	Hours Completed/Total Hours
Electrical	10/189
Software	100/140
Mechanical	120/284
Management	20/130
Total	250/743 (≈33%)

Budget

Project Overview | Project Schedule | Mechanical | Software | Electrical | System Integration | Budget

Cost Plan

Subsystem	Cost
Electrical	$308.26
Software	$1099.16
Mechanical	$3139.15
Miscellaneous	$127.41
Money Spent	**$4673.98**
EEF Grant	+$2500
Remaining Budget	**$2826.02**
Total	**$7500**



ENGINEERING EXCELLENCE FUND

Procurement Status- Remaining Items

Remaining Items		
Item	**Status**	**Estimated Delivery Date**
Motor	Ordered	February 20th
S-Band Feeds	Ordered	February 20th
Tripod	Ordered	February 8th
Travel Cases	Not Ordered	Needed by March 1st
Motor System Power Converters	Ordered	February 5th
Sheet Metal	Not Ordered	Needed by March 1st

Uncertainties: Delivery time from the Netherlands

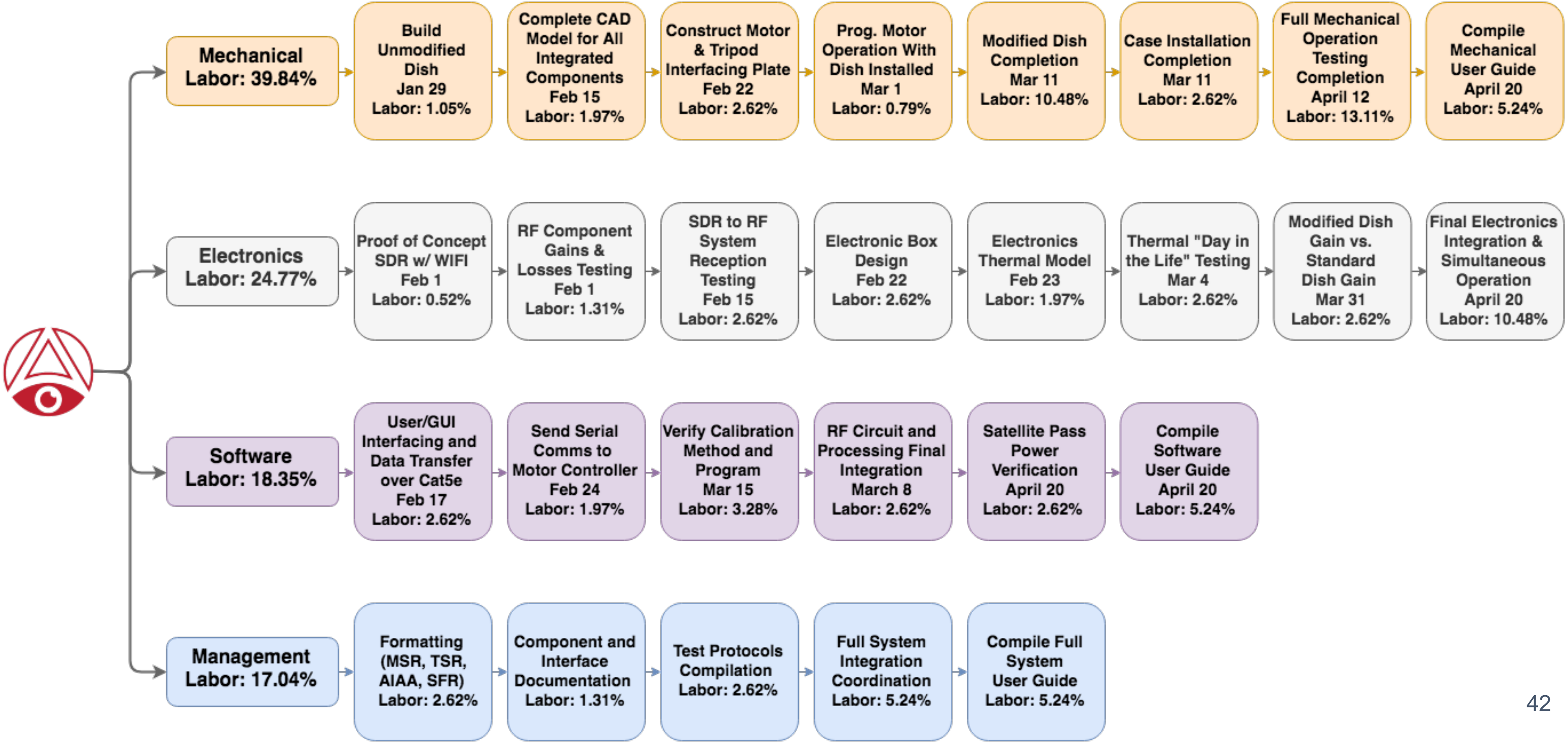
Questions?

Backup Slides

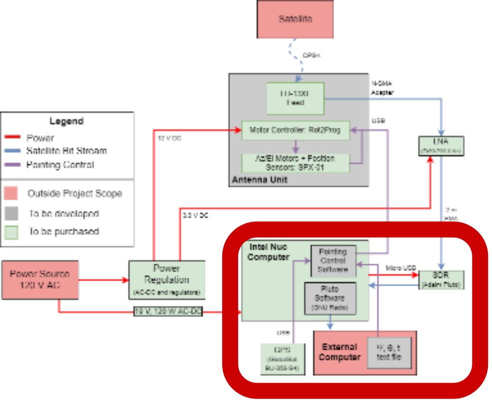
Software - Progress Report

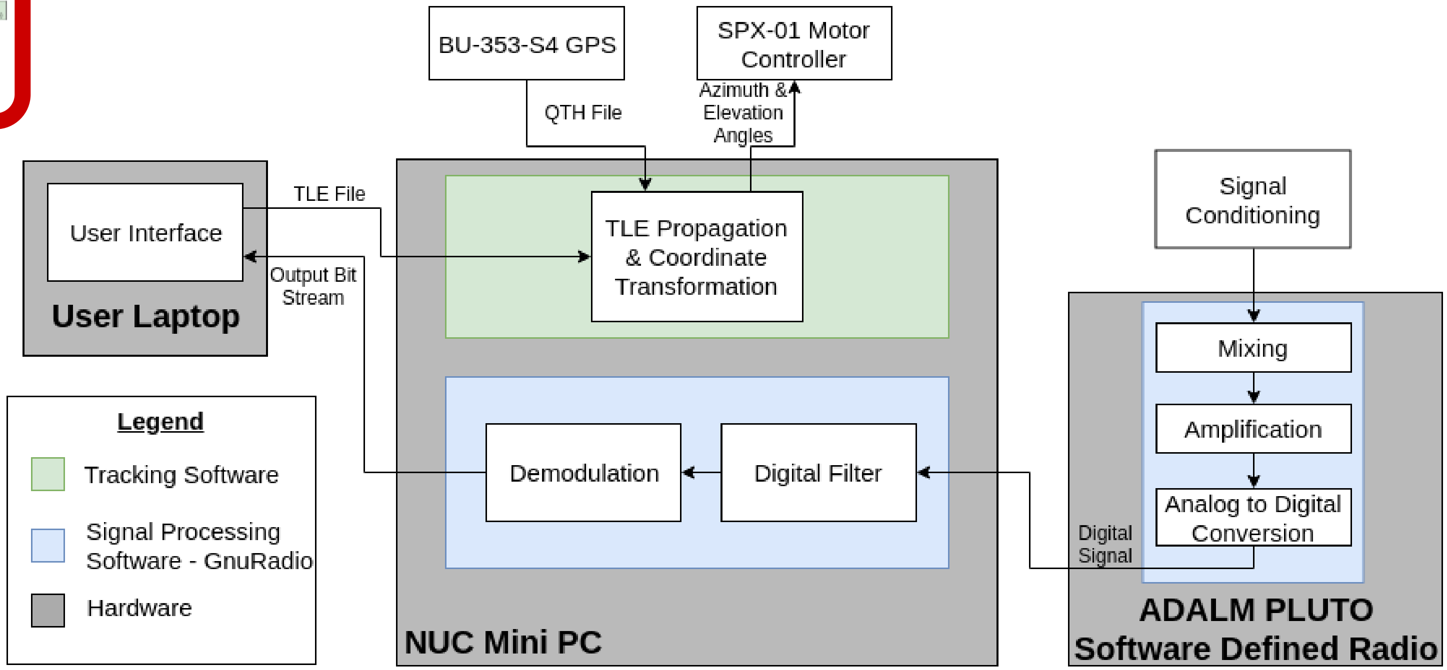
	Task	Hours Completed / Total Hours	Expected Deadline Date
Satellite Tracking	Predict Az/El over satellite pass	50 / 50	Completed
Software Interfacing	Laptop/NUC Interfacing	2 / 4	2/17/19
	Motor Interfacing	10 / 20	2/20/19
	User Interface	50 / 50	Completed
Data Reception	SDR data reception	40 / 50	2/10/19
	GPS data reception	10 / 10	Completed

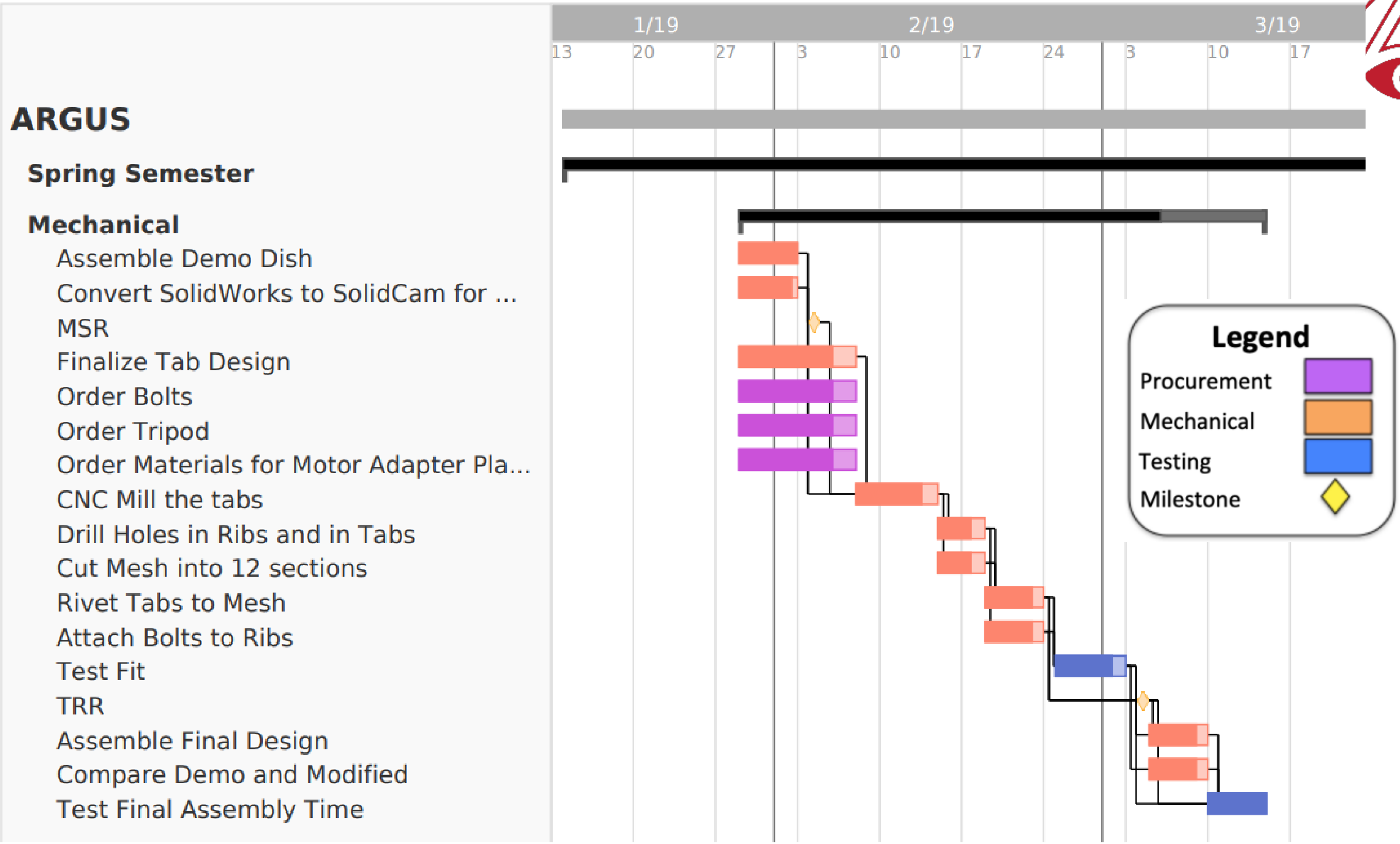
Task Breakdown Structure



Software Block Diagram






1/19
2/19
3/19
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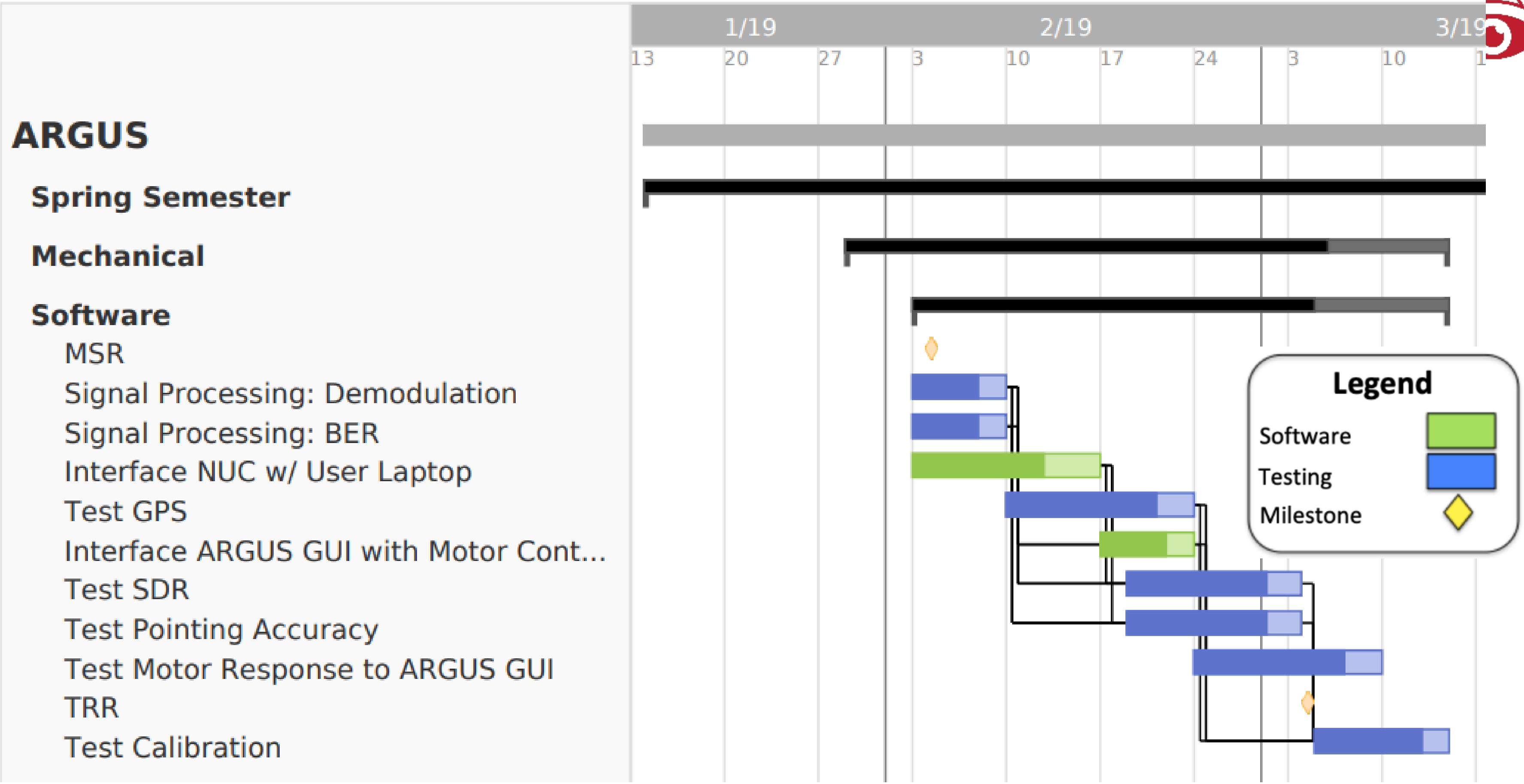
17
ARGUS
Spring Semester
Mechanical
Assemble Demo Dish
Convert SolidWorks to SolidCam for ...
MSR
Finalize Tab Design
Order Bolts
Order Tripod
Order Materials for Motor Adapter Pla...
CNC Mill the tabs
Drill Holes in Ribs and in Tabs
Cut Mesh into 12 sections
Rivet Tabs to Mesh
Attach Bolts to Ribs
Test Fit
TRR
Assemble Final Design
Compare Demo and Modified
Test Final Assembly Time
Legend
Procurement
Mechanical
Testing
Milestone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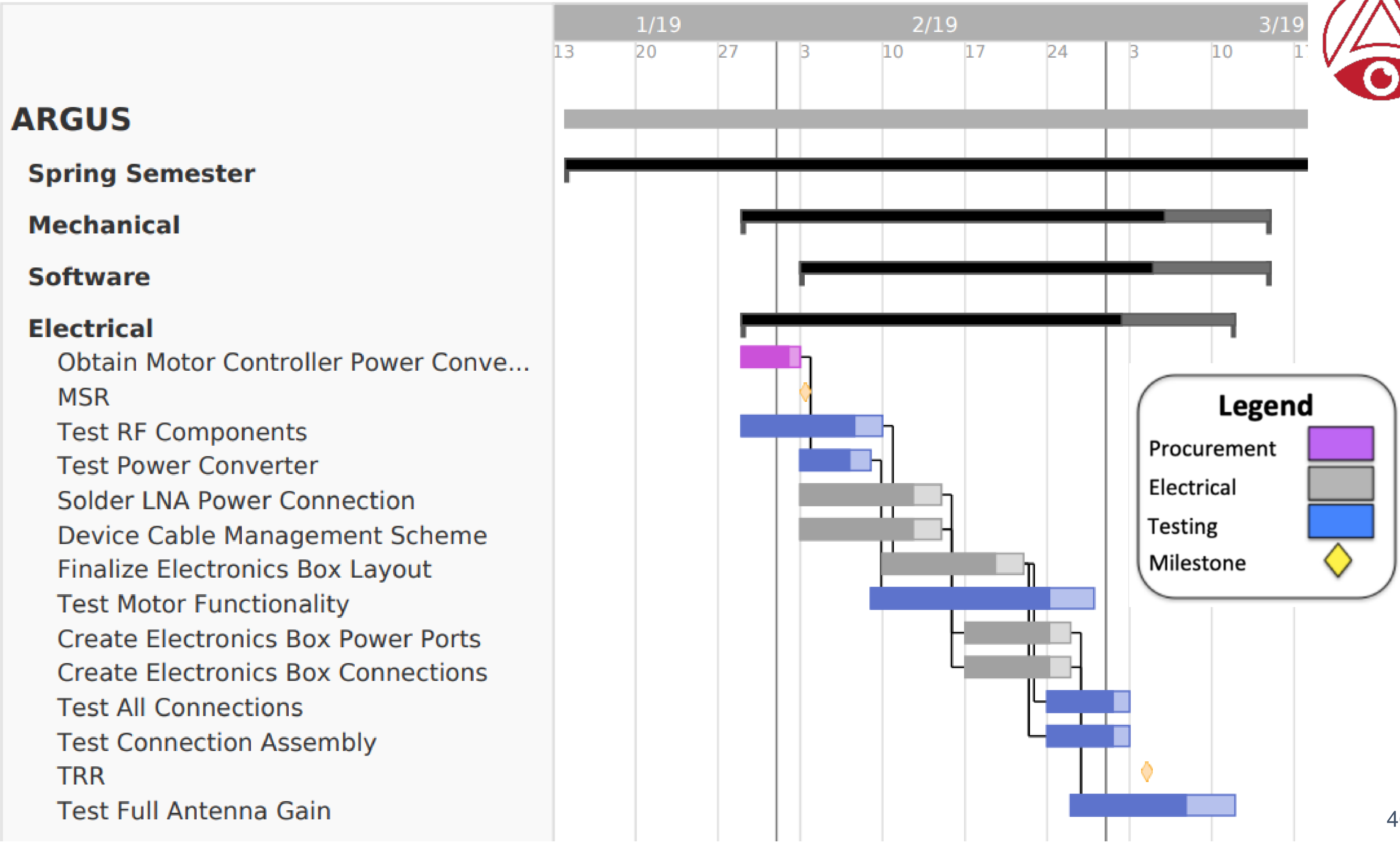
ARGUS
Spring Semester
Mechanical
Software
MSR
Signal Processing: Demodulation
Signal Processing: BER
Interface NUC w/ User Laptop
Test GPS
Interface ARGUS GUI with Motor Cont...
Test SDR
Test Pointing Accuracy
Test Motor Response to ARGUS GUI
TRR
Test Calibration
Legend
Software
Testing
Milestone


1/19
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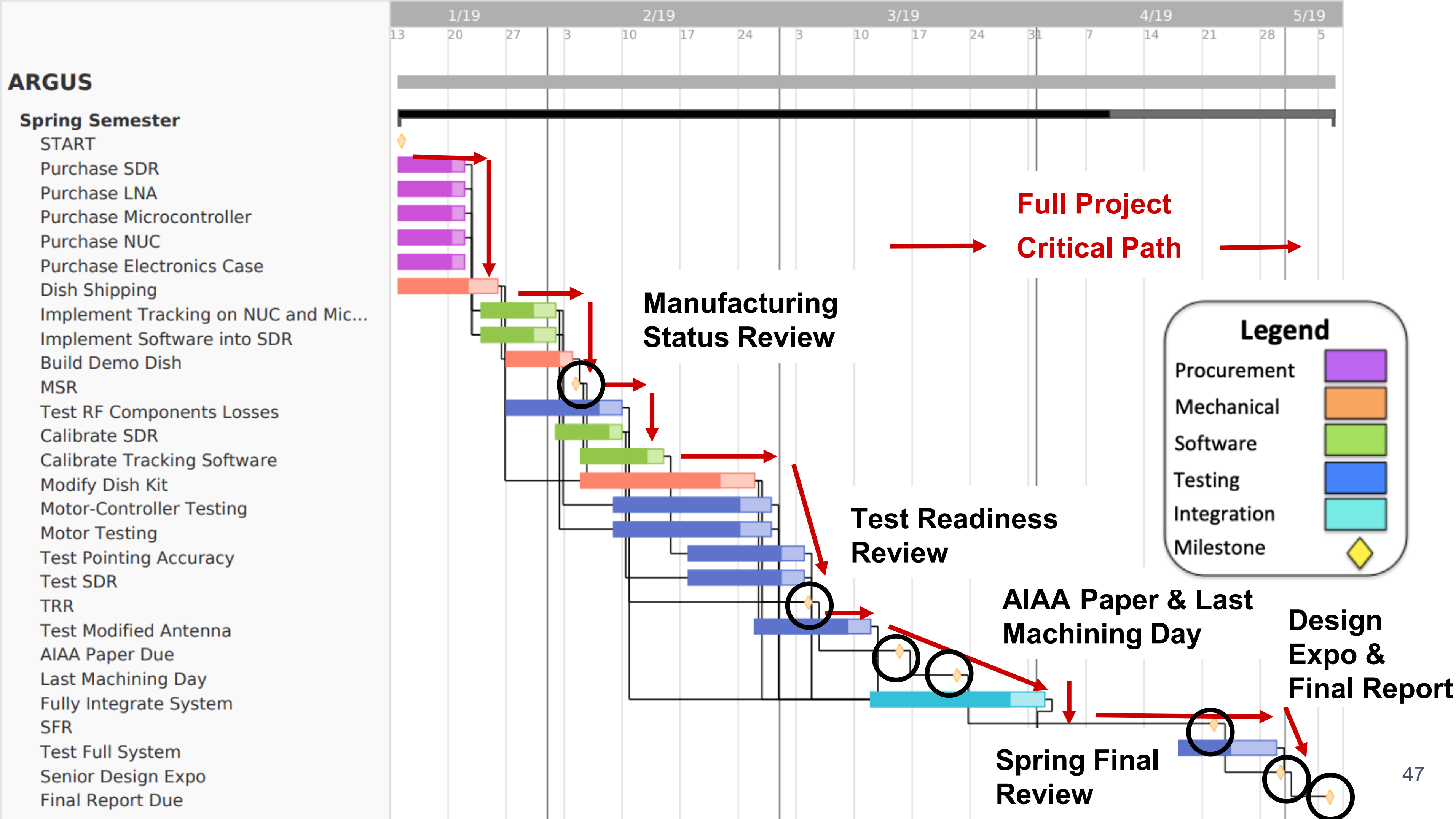
ARGUS
Spring Semester
Mechanical
Software
Electrical
Obtain Motor Controller Power Conve...
MSR
Test RF Components
Test Power Converter
Solder LNA Power Connection
Device Cable Management Scheme
Finalize Electronics Box Layout
Test Motor Functionality
Create Electronics Box Power Ports
Create Electronics Box Connections
Test All Connections
Test Connection Assembly
TRR
Test Full Antenna Gain
Legend
Procurement
Electrical
Testing
Milestone



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Legend
Procurement
Mechanical
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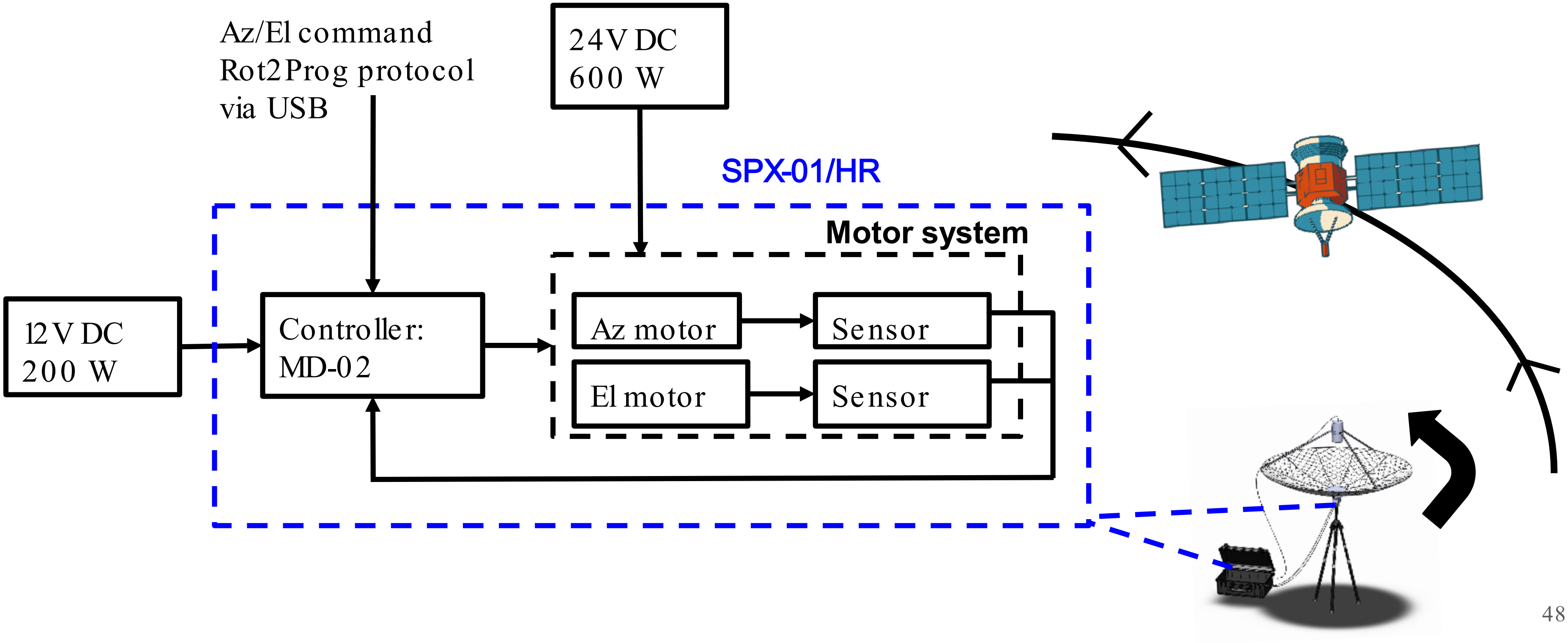
Milestone

Tracking Overview

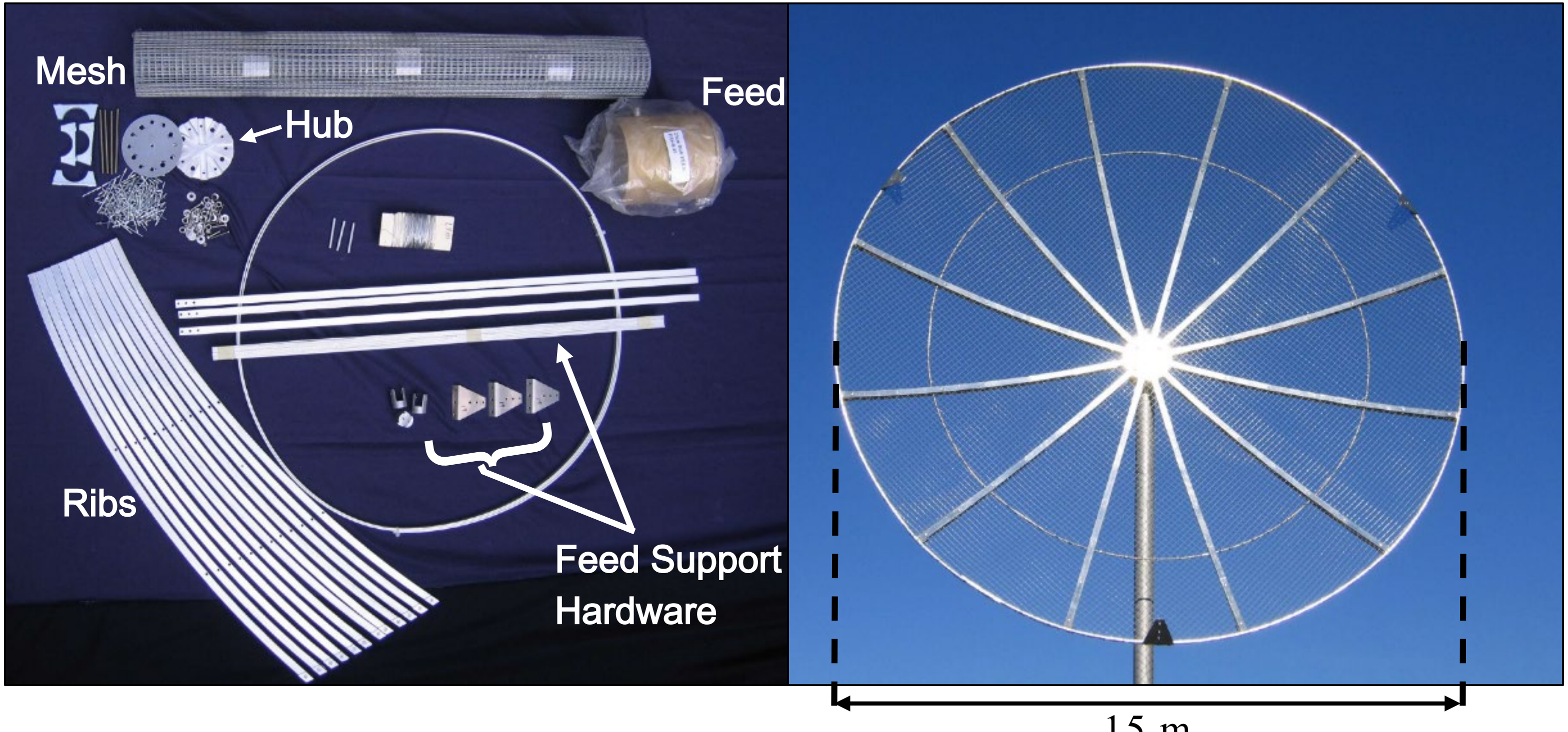


Design Requirements and Satisfaction

Antenna Subsystem

FR 1.0	The ground station shall be capable of receiving signals from a Low Earth Orbit satellite between 2.2 - 2.3 GHz, in Quadrature Phase Shift Keying (QPSK) modulation with a Bit Error Rate (BER) of 10^{-5}, a bit rate of 2 Mbit/s, and a G/T of 3 dB/K.
FR 4.0	ARGUS shall weigh less than 46.3 kg (102 lbs) and be capable of being carried a distance of 100 meters by two people.

RF Ham Design Reflector



- Meets specified 27 dB at 2.3 GHz requirement; however, fails to meet mobility requirement

Modification of Reflector

Current RFHam dish:

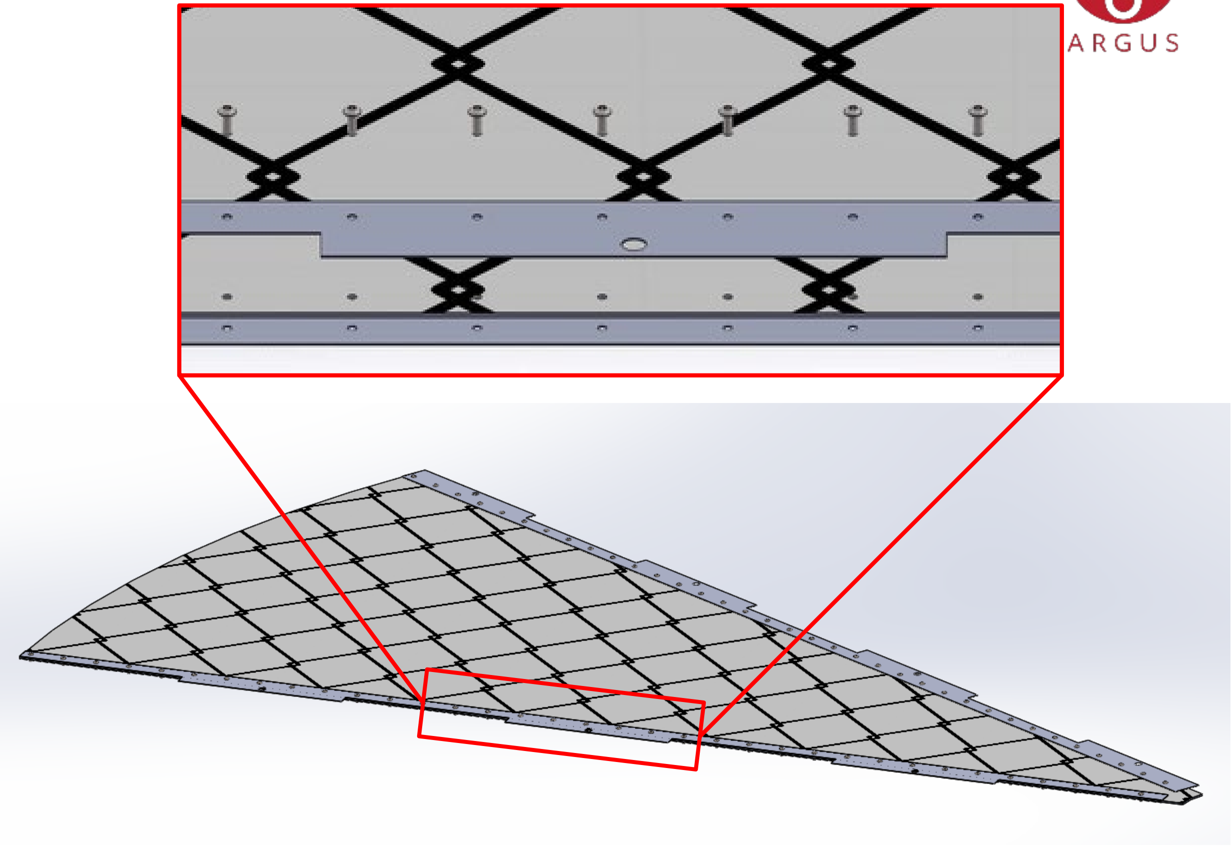
- Assembly time 6+ hours
- Single continuous mesh
- Multiple tools

Modifications:

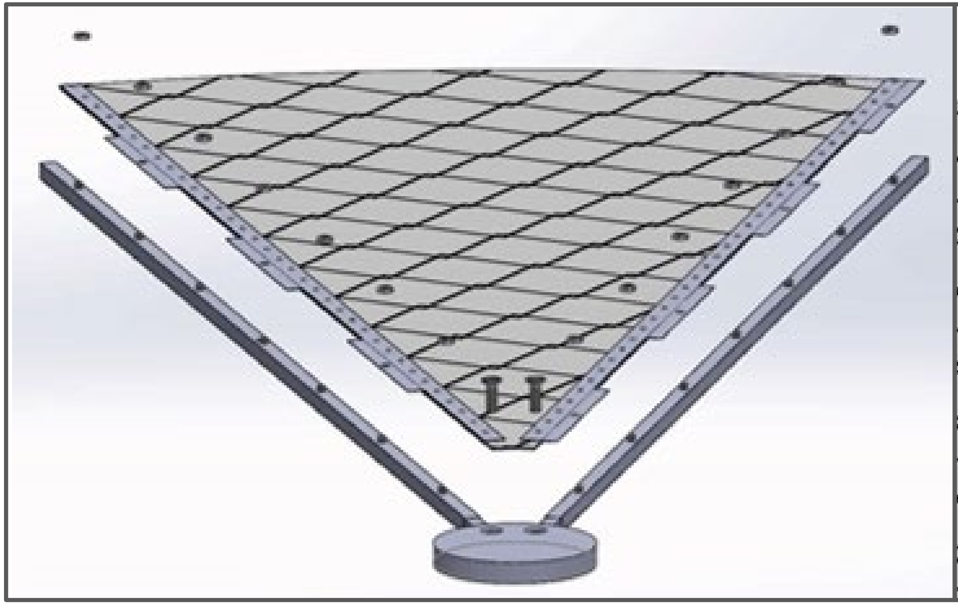
- Assembly time less than 1 hour
- Split into 12 connectable pieces
- Fewer than 4 tools

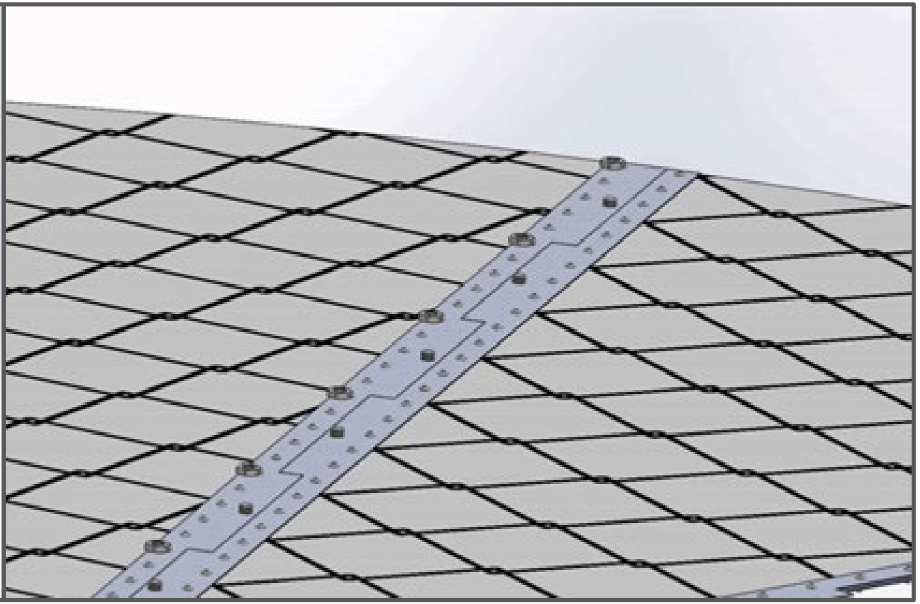
Modularity:

- 22 gauge aluminum sheet attaches to ribs
- Petals attach to central hub



Modification of Reflector





✔ □Meets mobility requirements (FR.4)

Antenna Gain Calculation

Pasternack SMA Male to N Male Adapter

- $L_1 = 0.07\ dB$

ZX60-P33ULN+ MiniCircuits LNA

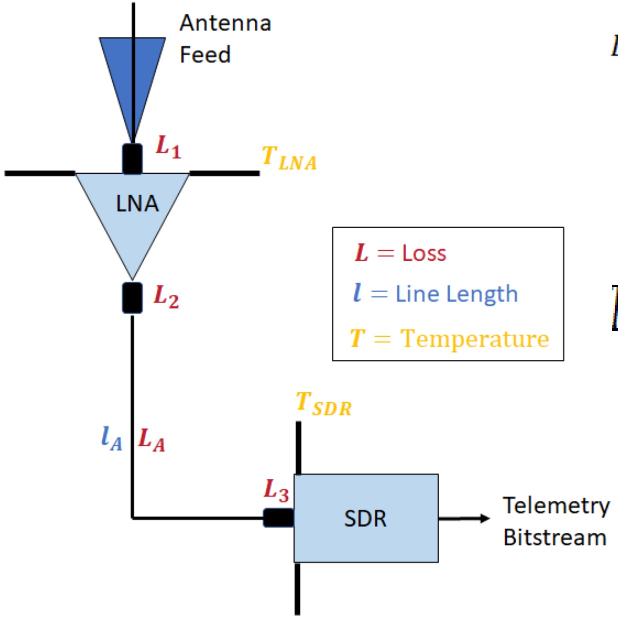
- $T_{LNA} = 44\ K$
- $G_{LNA} = 11.3\ dB$

Pasternack SMA to SMA Cable

- $l_A = 2\ m, 0.7\ \frac{dB}{m} \Longrightarrow L_A = 1.4\ dB$
- $L_2 = L_3 = 0.45\ dB$

Adalm-Pluto SDR

- $T_{SDR} = 288.6\ K$



$$L_{tl} = L_1 + L_2 + L_3$$

$$10^{-L_{tl}}$$

$$T_s = aT_a + (1-a)T_0 + T_{LNA} + \frac{l\ldots}{G_{LN\ldots}}$$

$$\Rightarrow T_s = 140K$$

Requirement: $\frac{G}{T_s} = 3\frac{dB}{K}$

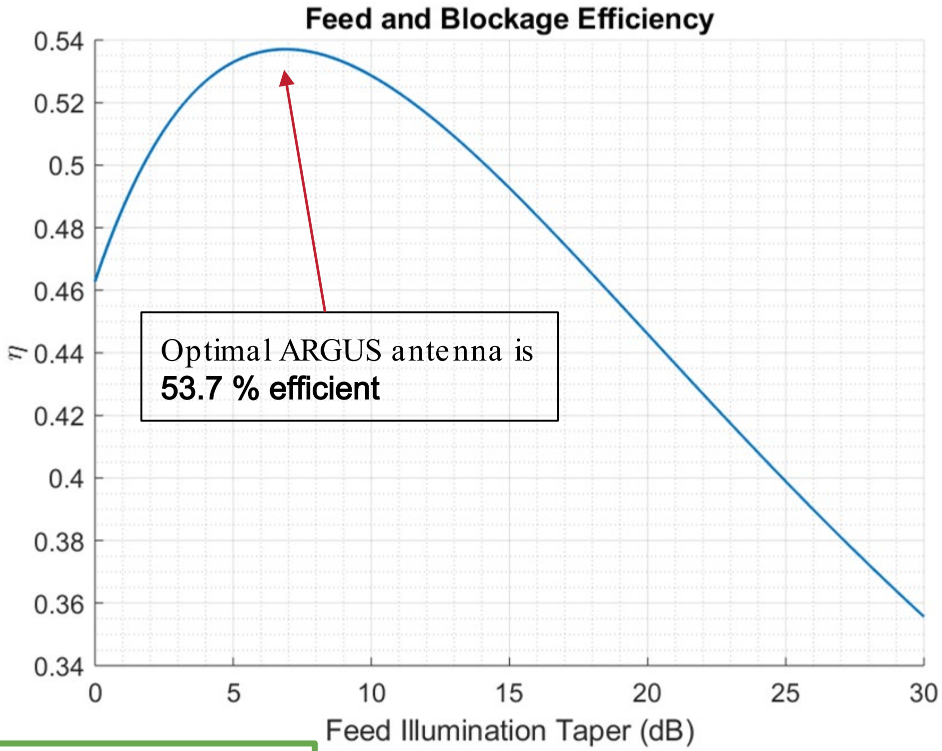
$$G_{required} = 26.2\ dBi$$

Estimated Efficiency

$$\eta = \eta_{feed}\eta_{bl}$$

$$G_{parabolic} = \eta\left(\frac{\pi D}{\lambda}\right)^2$$

Gain at **53.7%** efficiency	28.08 dBi
Gain at **35%** efficiency	26.22 dBi
Required gain	26.2 dBi



✔ ☐Meets bandwidth and gain requirements (FR.1)

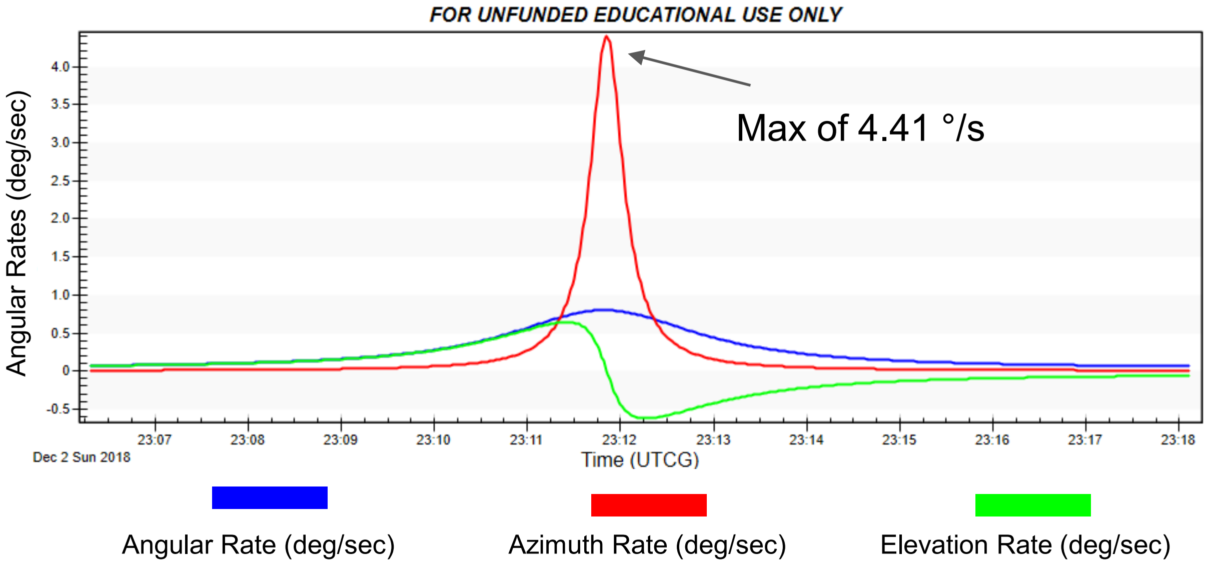
Tracking Hardware Subsystem

FR 2.0	The ground station shall mechanically steer a dish/antenna system to follow a LEO satellite between 200 km to 600 km between 10° elevation and 170° elevation.

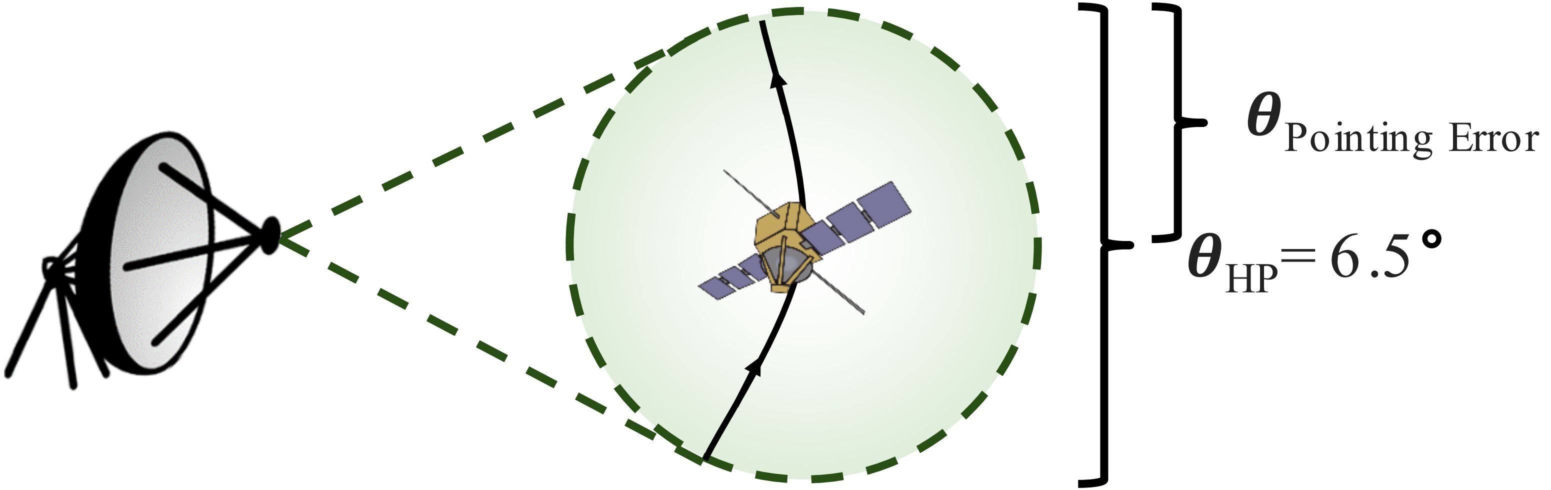
STK: Tracking Rate Verification

DR 2.3	The antenna motor shall be able to move the antenna at a slew rate of **5.0 °/s**

- Worst case pass
  - Elliptical orbit
  - Pass directly overhead
  - Retrograde
- Max Rate: 4.41°/s



Worst Case Pointing Error



$$\theta_{Pointing\ Error} = \theta_{TLE,\ Error} + \theta_{Motor,\ Error} + \theta_{Tracking,\ Error} < 3.25°$$

$$\theta_{Motor,\ Error} < 3.25° - 1.10° - 1.43°$$

$$\theta_{Motor,\ Error} < 0.72°$$

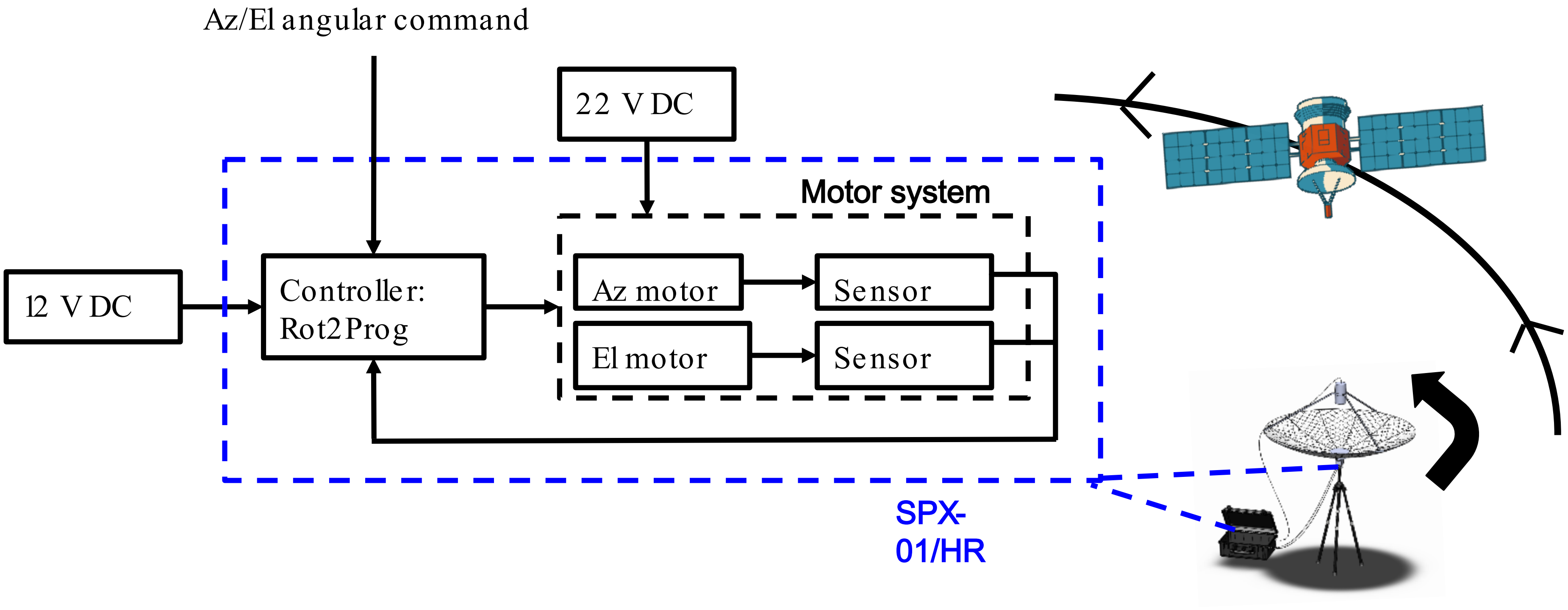
$$\theta_{TLE,\ Error,\ Max} = 1.43°$$
$$\theta_{Tracking,\ Error,\ Max} = 1.10°$$

Antenna Motor System

- Specs:
  - Azimuth
    - Range: 0° to 360°
    - Speed: 7.2°/sec
  - Elevation
    - Range: ± 90°
    - Speed: 7.2°/sec
  - Maximum Load: 30 kg
  - Position sensors with accuracy: 0.2°
  - Mass: 17.8 kg

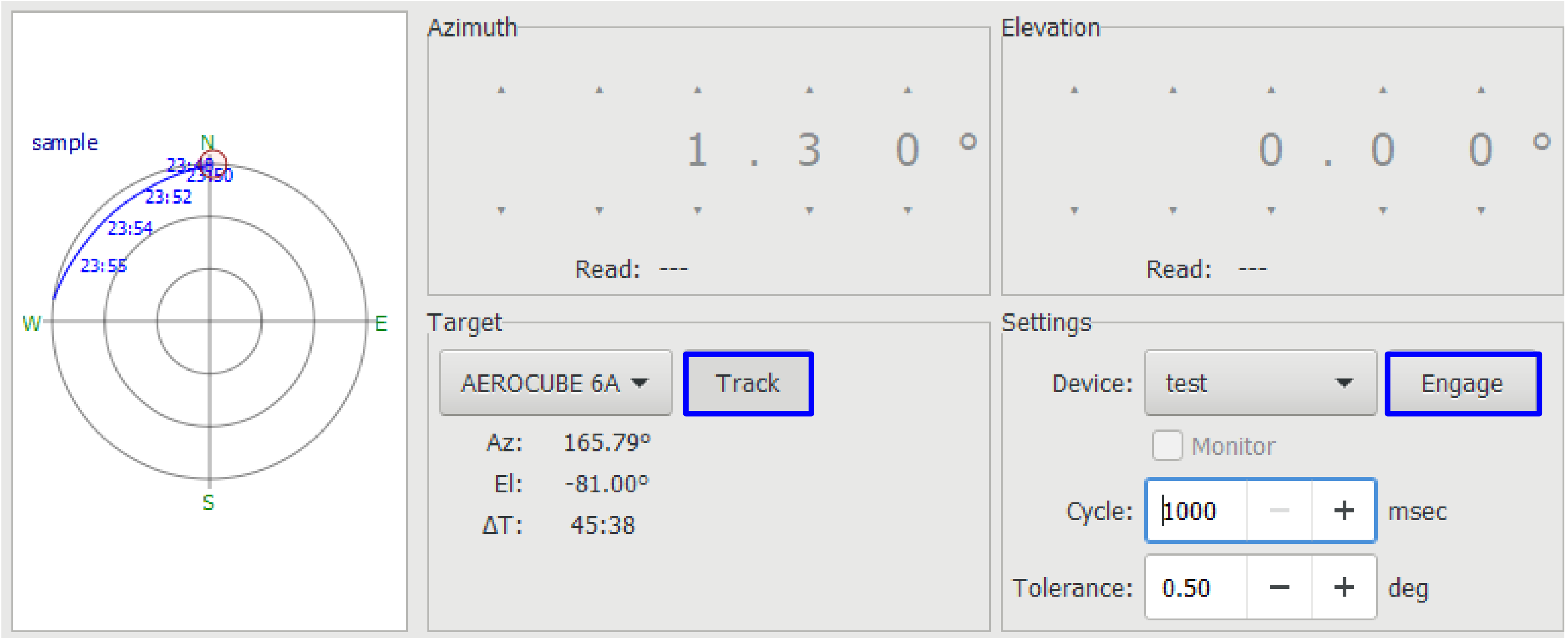
✓	DR 2.3	The antenna motor shall be able to move the antenna at a slew rate of **5.0 °/s**
✓	DR 2.4	The antenna motor shall have a pointing accuracy greater than **0.72°**

Tracking Overview



Software Interface

Enable serial communication ➡ Input lat/long ➡ Calibrate ➡ Select target ➡ Engage

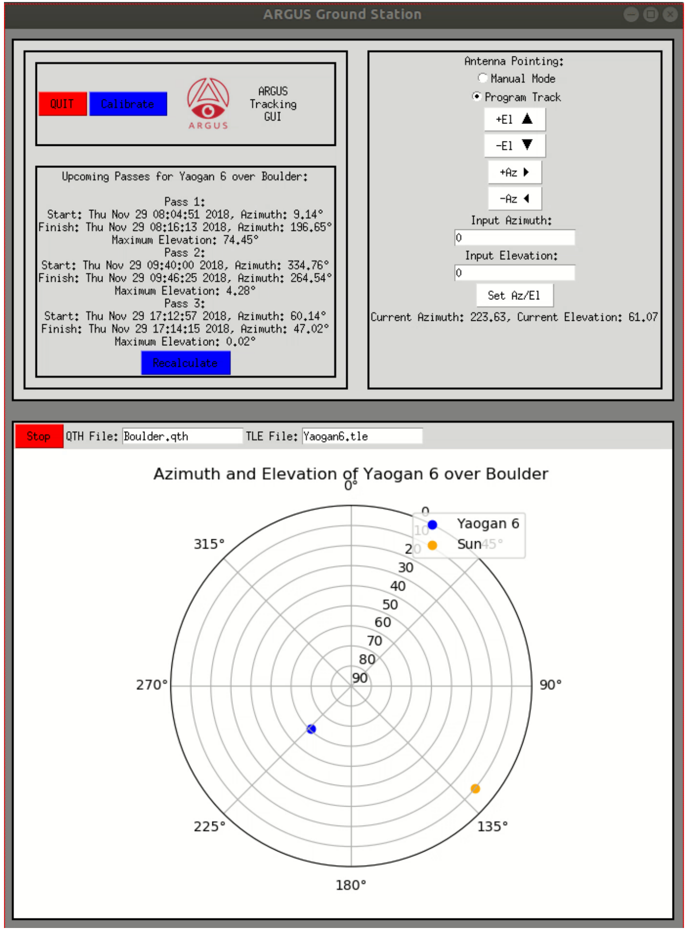


Tracking Software Subsystem

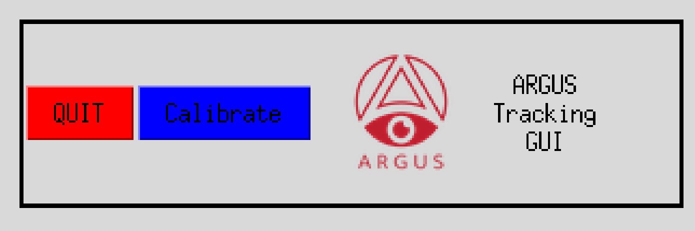
FR 2.0	The ground station shall mechanically steer a dish/antenna system to follow a LEO satellite between 200 km to 600 km between 10° elevation and 170° elevation.

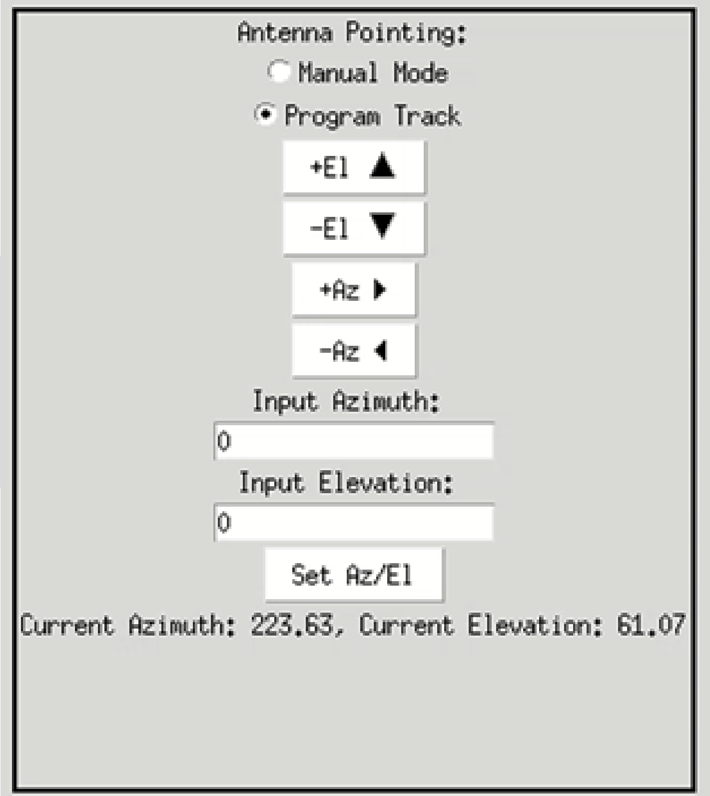
Tracking Software Demonstration

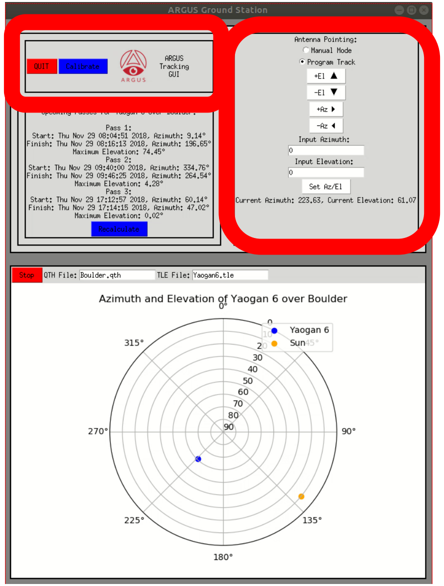
FR 2.0	The ground station shall mechanically steer a dish/antenna system to **follow a LEO satellite** between 200 km to 600 km between 10° elevation and 170° elevation.



Calibration & Manual Control Frames

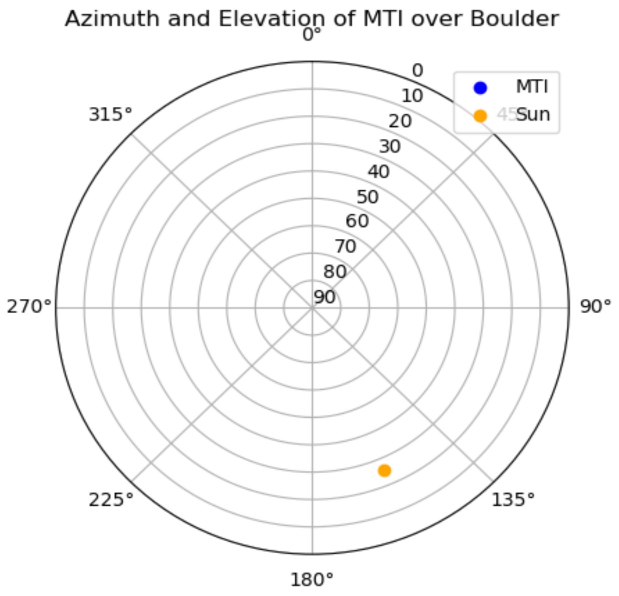






Azimuth and Elevation Calibration

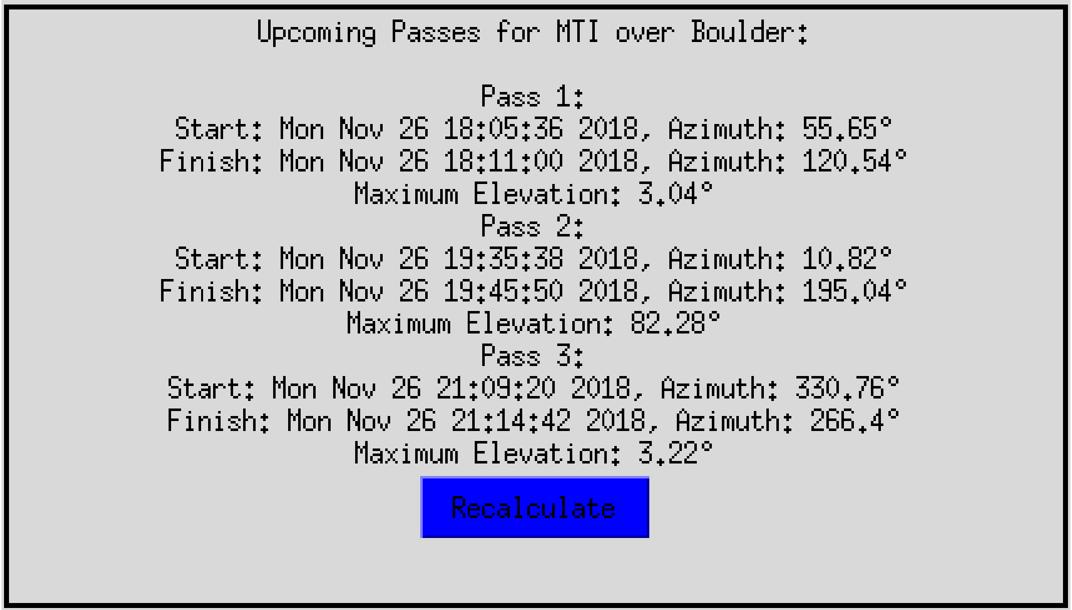
DR 2.2	The pointing control accuracy must be within **3.25°** to maintain downlink capabilities throughout the entire pass.

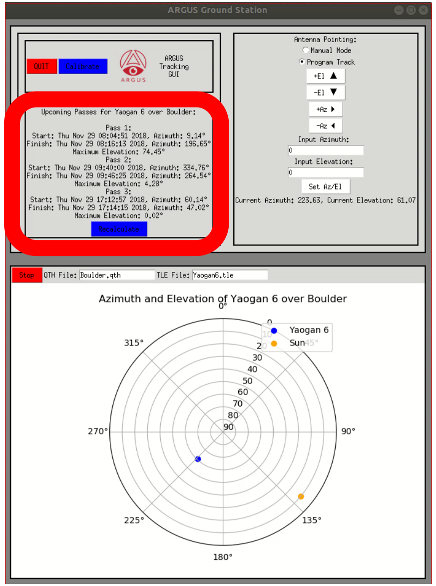


- Manual Control Frame - Dither around Sun, find strongest signal strength
- Calibration Frame - Set current pointing angles to predicted Sun location

Ground Station Latitude/Longitude (GPS) → ARGUS GUI → Sun Azimuth and Elevation → Point in Predicted Location and Dither

Upcoming Pass Frame





STK: Upcoming Pass Verification

DR 2.2	The pointing control accuracy must be within **3.25°** to maintain downlink capabilities throughout the entire pass.

ARGUS (Mountain Time)

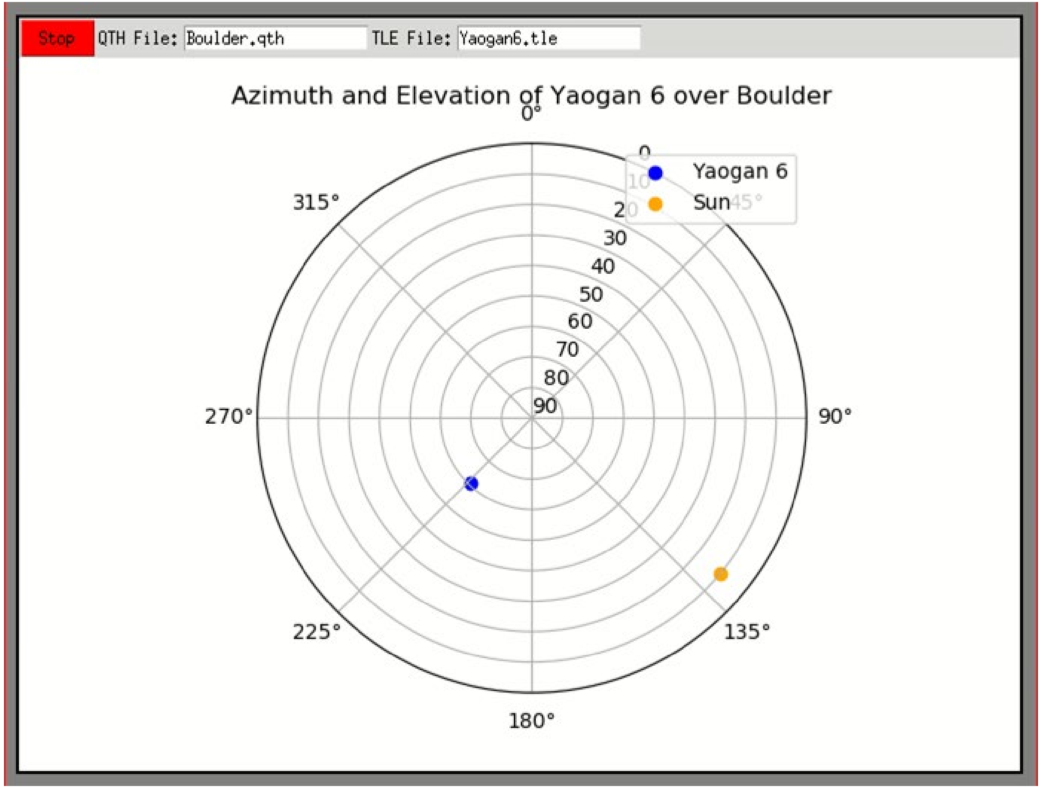
```
Upcoming Passes for MTI over Boulder:

Pass 1:
Start: Sun Dec  2 18:03:20 2018, Azimuth: 60.53°
Finish: Sun Dec  2 18:08:01 2018, Azimuth: 115.76°
Maximum Elevation: 2.1°
Pass 2:
Start: Sun Dec  2 19:32:59 2018, Azimuth: 12.35°
Finish: Sun Dec  2 19:43:11 2018, Azimuth: 192.14°
Maximum Elevation: 84.43°
Pass 3:
Start: Sun Dec  2 21:06:27 2018, Azimuth: 333.89°
Finish: Sun Dec  2 21:12:18 2018, Azimuth: 262.7°
Maximum Elevation: 4.08°
Recalculate
```

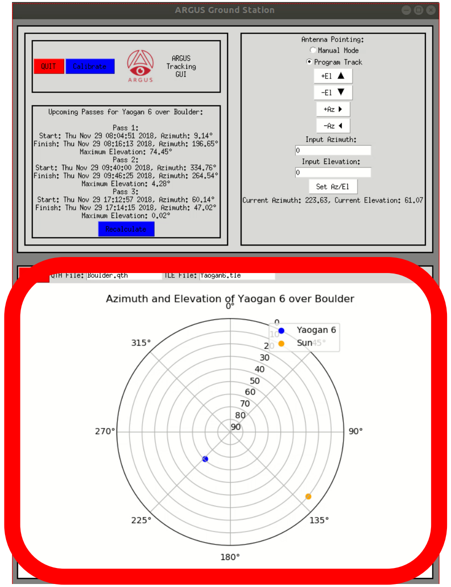
Place1-To-Mti_26102

Access	Start Time (UTCG)	Stop Time (UTCG)
2	3 Dec 2018 02:32:58.799	3 Dec 2018 02:43:11.240

✔☐Verified

Az/El Plot Frame

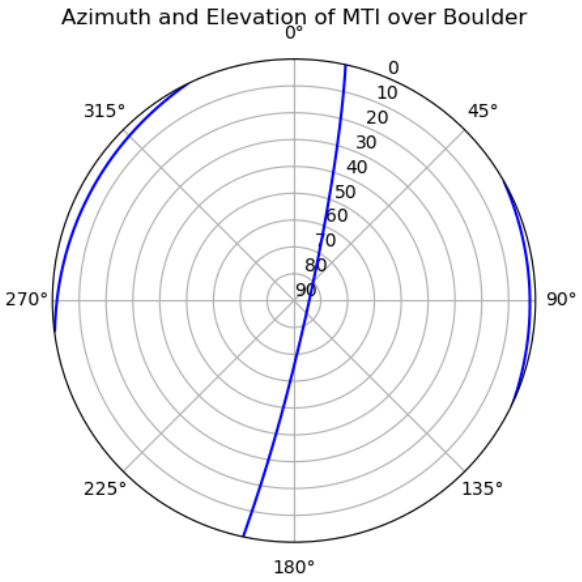




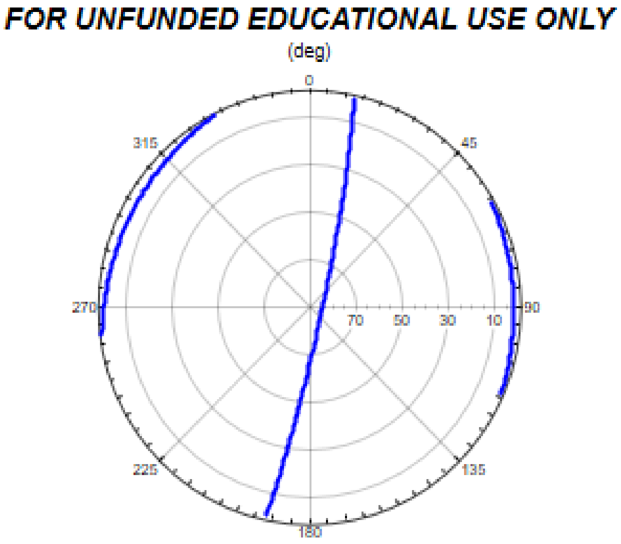
STK: Azimuth/Elevation Verification

DR 2.2	The pointing control accuracy must be within **3.25°** to maintain downlink capabilities throughout the entire pass.

ARGUS



STK



Signal Conditioning & Processing

FR 1.0	The ground station shall be capable of receiving signals from a Low Earth Orbit satellite between 2.2 - 2.3 GHz, in Quadrature Phase Shift Keying (QPSK) modulation with a Bit Error Rate (BER) of 10^{-5}, a bit rate of 2 Mbit/s, and a G/T of 3 dB/K.

GNURadio Software Diagram

Adalm Pluto SDR → Digital Filtering → Demodulation → GUI

Adalm Pluto SDR

- Frequency: 2.2-2.3 GHz
- Bit Rate: 2 MHz
- Mixing
- Amplify
- ADC

Digital Filtering

- Low Pass

Demodulation

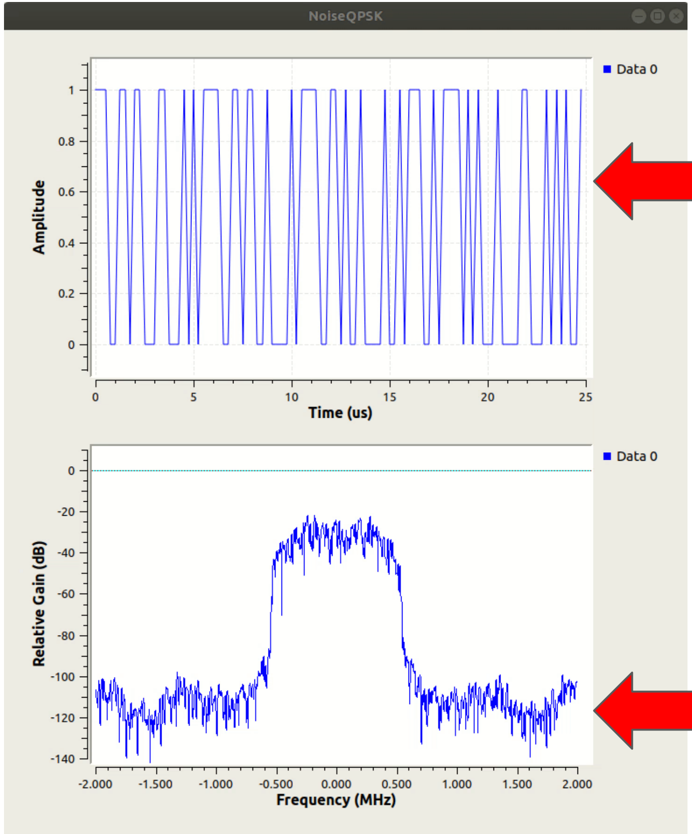
- QPSK

GUI

- FFT Plot
- Bit Plot

FR 1.0	The ground station shall be capable of receiving signals from a Low Earth Orbit satellite between **2.2 - 2.3 GHz**, in **Quadrature Phase Shift Keying (QPSK) modulation** with a Bit Error Rate (BER) of 10^{-5}, **a bit rate of 2 Mbit/s** , and a G/T of 3 dB/K.

GNURadio Software Demonstration



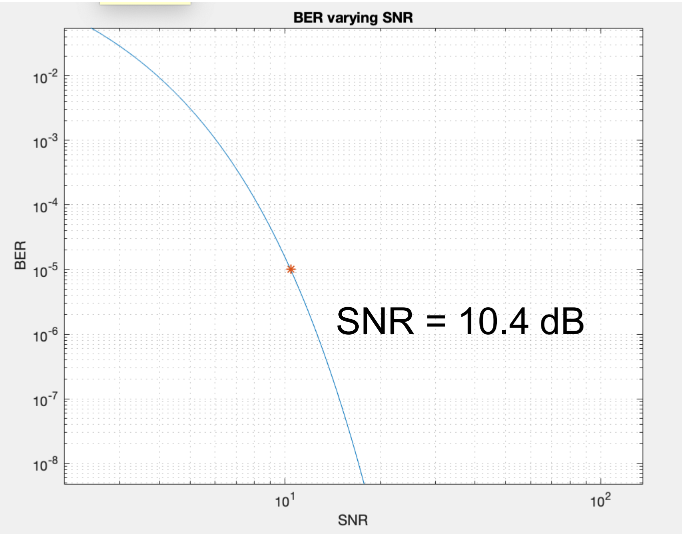
DR 1.4	The ground station shall be capable of demodulating a signal using the QPSK modulation scheme.
DR 1.10	The ground station shall be able to receive a data rate of at least 2 million bits per second.

Bit Error Rate

FR 1.0	The ground station shall be capable of receiving signals from a Low Earth Orbit satellite between 2.2 - 2.3 GHz, in Quadrature Phase Shift Keying (QPSK) modulation with **a Bit Error Rate (BER) of 10^{-5}**, a bit rate of 2 Mbit/s, and a G/T of 3 dB/K.

BER is governed by the system Signal to Noise Ratio (SNR)

- Must have SNR ≥ 10.4dB to achieve BER of 10^{-5}
- Current system SNR ≅ 17.21dB
  - BER ≅ 8.9e-9
  - Determined using ASEN 3300 link budget and typical transmit values



✔ ☐Meets Requirement

Mobility

FR 4.0	ARGUS shall weigh less than 46.3 kg (102 lbs) and be capable of being carried a distance of 100 meters by two people.

Mobility: Mass Estimate

Components	Mass	Components	Mass
Feed	1 kg	Tripod	5 kg
Dish + connecting tabs	7 kg	SDR	0.12 kg
Az/El motors	12.8 kg	Electronics	2.2 kg
Motor Controller	5 kg	Case	8.4 kg
NUC	1.2 kg	AC-DC converters	2.3 kg
Total	**45.0 kg < 46.3 kg**	✔ ☐Meets Mass Requirement **(FR4.0)**	

Verification and Validation

Test Plan

Component Test:
Jan. 15th - Feb. 11th

Antenna:
- Dish manufacturing
- Motor calibration
- Feed functionality

Signal Processing:
- GNURadio
- Predict
- GPS

Hardware:
- Power Transformer
- Capacitor
- Motor Functionality
- Component weights

Integration Test:
Feb. 11th - Mar. 11th

Antenna System:
- Gain
- Beamwidth

Signal Processing Test:
- QPSK demodulation
- BER
- Cat5 connection

Motor System Test:
- Rotation rate
- Rotation range

Systems Test:
Mar. 11th - April 21st

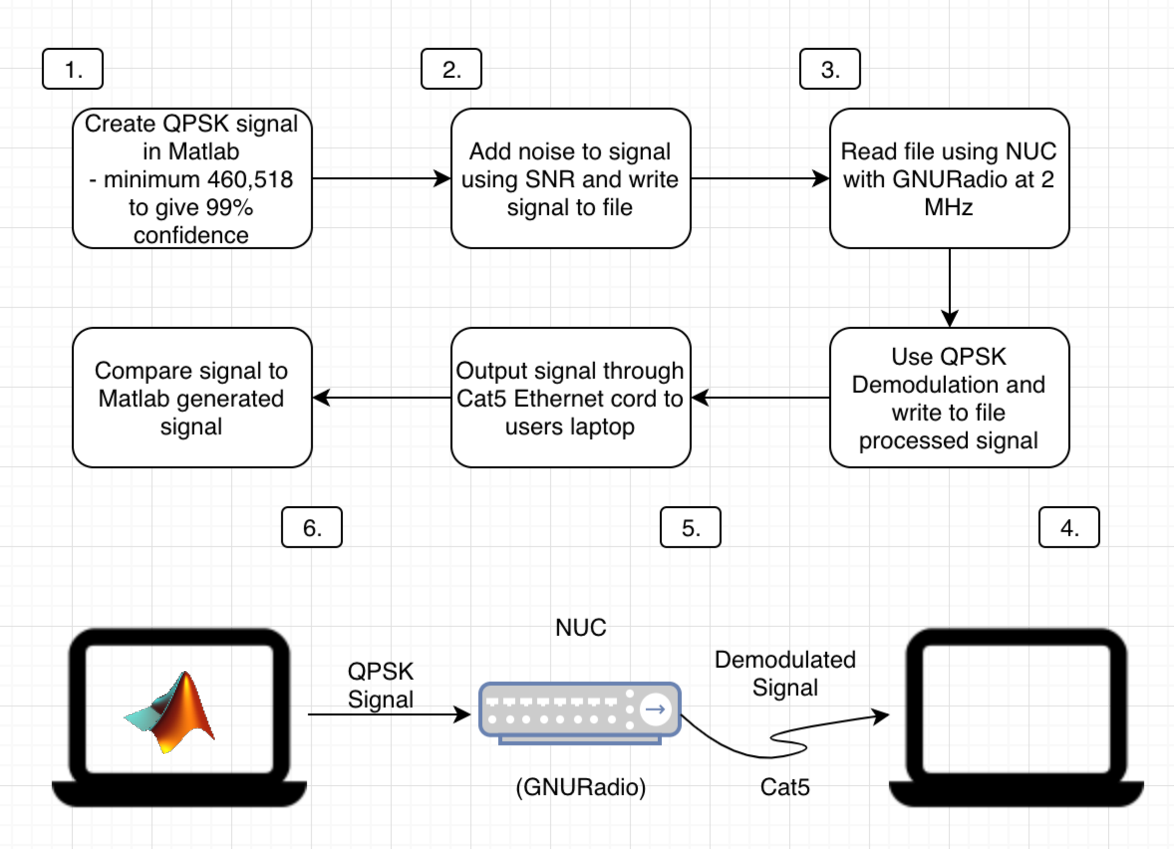
Antenna System:
- S-Band satellite signal reception

Signal Processing Test:
- S-Band signal processed

Motor System Test:
- MTI + Yaogan 6 tracking

Mobility:
- Transport and assembly > 100m

Signal Processing System Level Test



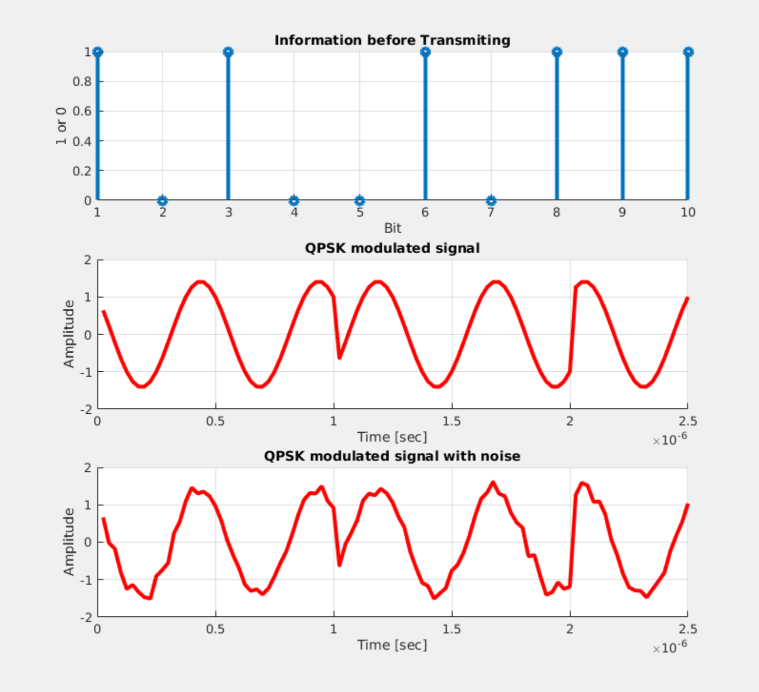
Equipment Needed	Procurement
Laptop	Owned
GNURadio	Open Source

Possible Measurement Errors
• NUC Processing Speed • Reconfigurability • Length of test (time)

Signal Processing System Level Test

Objective	• Verify NUC Processing speed • Cat5 data port connection • GNURadio on S-Band signal
Location	ITLL
FR Verified	FR 1: BER, QPSK Demodulation, Bandwidth FR 3: Reconfigurability FR 5: Cat5 Connection

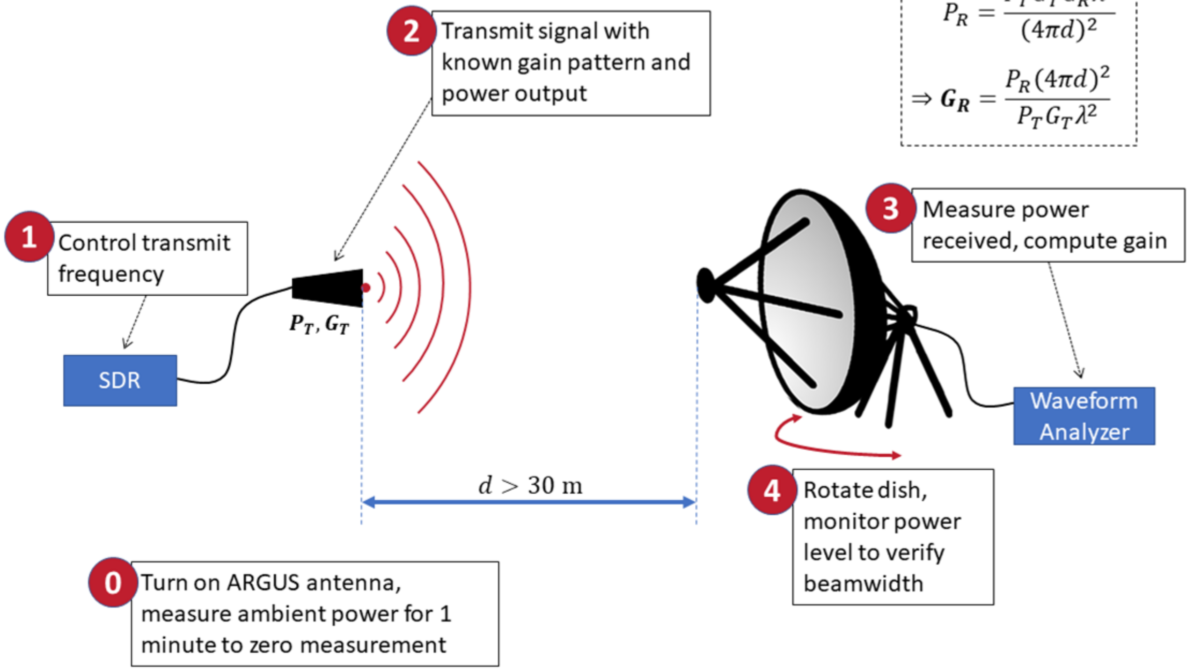
Data Needed	Compared To	Expected
BER	Matlab estimation	8.9E-9
QPSK Signal	Matlab generated signal	Matlab generated signal



Antenna Gain/Beamwidth Test

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi d)^2}$$

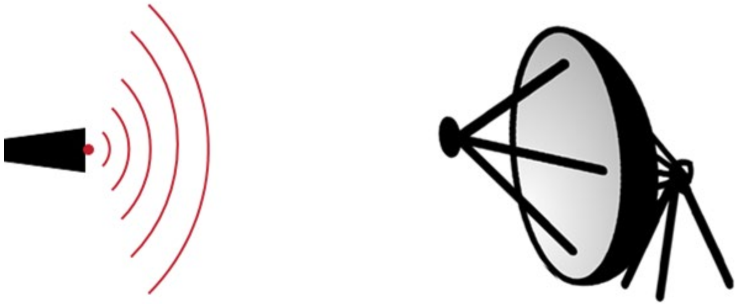
$$\Rightarrow G_R = \frac{P_R (4\pi d)^2}{P_T G_T \lambda^2}$$



Equipment Needed	Procurement
SDR	Purchase
Transmit Antenna	Borrow/Purchase
Waveform Analyzer	Borrow
Measuring wheel	Borrow

Antenna Gain/Beamwidth Test

Objective	• Verify antenna gain • Verify half power beam width (HPBW)
Location	Rural location or RF test range
FR Verified	FR 1: Gain, Beamwidth

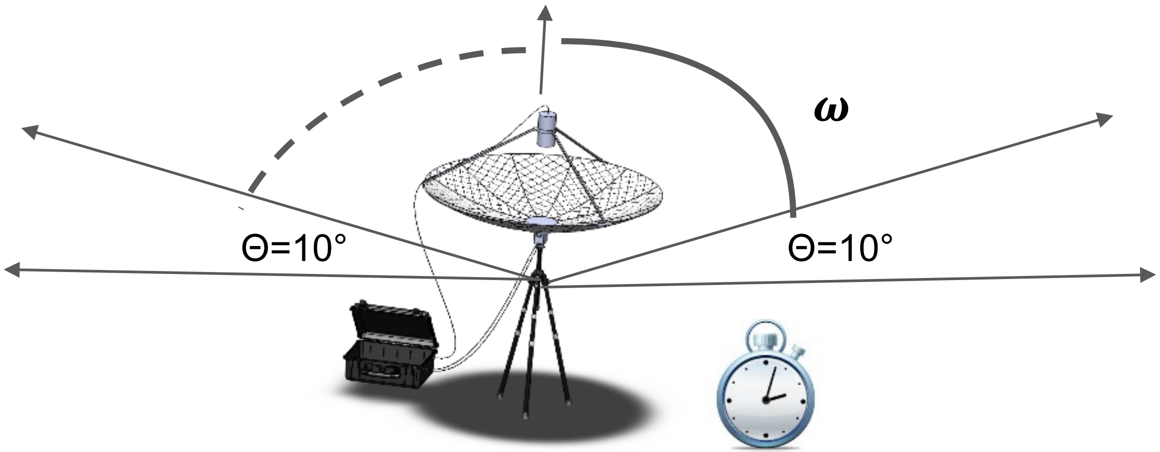


Data Needed	Compared To	Expected
Gain	Efficiency model, dish kit specs	29.5dBi at 2.4GHz
Beamwidth	Idealized estimates, dish kit specs	6.5°

Potential Measurement Issues
• External signal noise • Signal reflection from ground • Incorrect feed placement • Pointing accuracy

Motor System Level Test

1. Attach Dish+Feed to motor system. Includes tripod and cable
2. Use motor controller to slew antenna between 10-170 degrees
3. Measure rotation time to calculate slew rate



Equipment Needed	Procurement
Timer	Owned
Protractor	Borrow
Power Supply	Borrow

Motor System Level Test

Objective	• Test cable wrap • Show motor control system • Test encoders
Location	ITLL
FR Verified	FR 2: Slew rate, range of motion

Data Needed	Resolution	Expected
Rotation Rate	0.2°/s	7.2 °/s
Rotation Angle	1°	10°-170°

Possible Measurement Errors
• Timing accuracy • Angle measurement accuracy

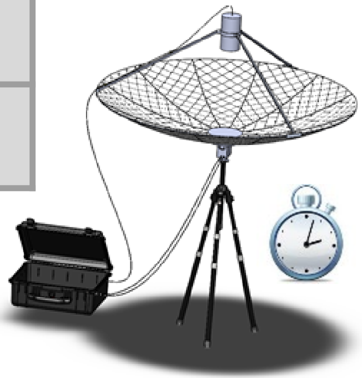
Mobility System Level Test

Equipment Needed	Procurement
Scale	Borrow
Measuring wheel	Borrow
Stopwatch	Borrow/Owned

1. All ARGUS components packed in carrying case

2. Weigh disassembled system

3. Carry 100m



4. Assemble ARGUS

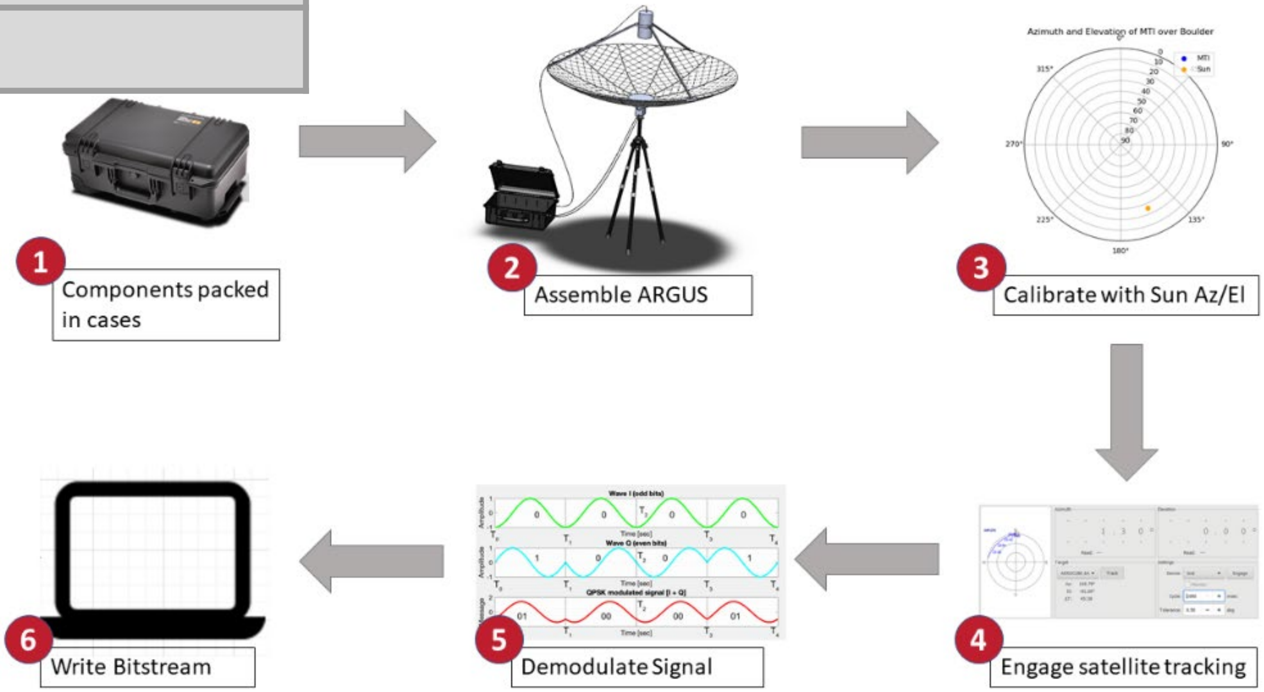
Mobility System Level Test

Objective	• Verify weight requirements • Demonstrate mobility • Show assembly is under 60min
Location	Business field
FR Verified	FR 4: Mass, assembly time

Data Needed	Requirement	Expected
Weight	46.3 kg	45.4 kg
Assembly Time	60 min	35 min

Full System Test

Objective	• Test ARGUS portability • Receive signal from satellite
Location	Business Field
FR Verified	All FR



Looking Forward

- **Critical items to be worked on:**
  - Modified Antenna
    - Parabolic Dish
  - Signal Processing
  - Interface ARGUS GUI on Motor Controller
- **Tests**
  - SDR
  - GPS
  - RF Components
  - Motor Functionality
  - Connections